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CONTENTS

The Place of the Bell Telephone Laboratories in the Bell System
W. S. GIFFORD

Bell Telephone Laboratories, Inc.
JOHN MILLS

Our Timber Problem
F. L. RHODES

The Development of the Transmission Circuit in Communication
J. O. PERRINE

Open Tank Creosoting Plants for Treating Chestnut Poles
T. C. SMITH

The Growth of the Historical Collection
W. C. LANGDON

Abstracts of Recent Technical Papers from Bell System Sources

Notes on Recent Occurrences—Organization Changes

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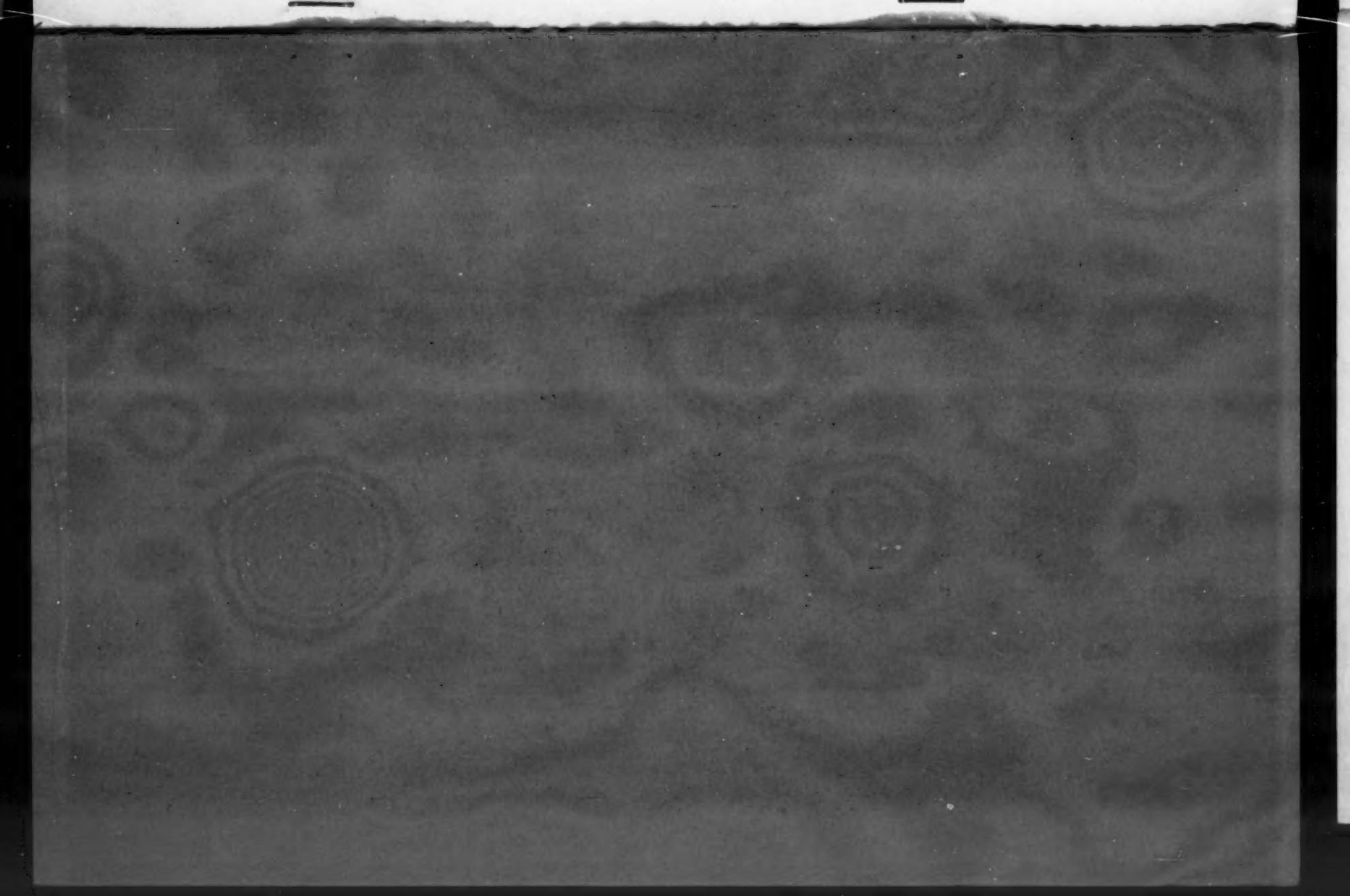

BELL TELEPHONE QUARTERLY

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The Place of the Bell Telephone Laboratories in the Bell System

IT is one of the functions of the American Telephone and Telegraph Company to work out for its Associated Companies engineering problems involving new developments. These problems as met by one company are, in large measure, common to all the companies, so that the solutions when once at hand are generally applicable and benefit all. The centralization of the study of such problems is almost imperative in order to unify the plant and the operating practices throughout the country, a prerequisite to the interconnection of subscribers on a nationwide basis.

Since the development problems encountered by the Associated Companies cover all branches of telephone engineering, there have arisen in the American Telephone and Telegraph Company or closely associated with it three organizational branches for participating in the solution of these problems, its Department of Operation and Engineering, its Department of Development and Research, and the Bell Telephone Laboratories.

The American Telephone and Telegraph Company undertakes, through constant association with the

operating organizations of the Associated Companies, to formulate the requirements, present and future, of the Bell System. Out of these requirements come the problems of the Department of Development and Research and the Bell Telephone Laboratories. Broadly speaking, the work of these departments may be grouped under one or the other of two classifications depending upon whether it has been initiated in response to some operating problem which is pressing for solution or initiated as a step in the American Company's broad fundamental programs of development. Work of the former character is necessarily carried on in much closer contact with the engineers in the operating field than work of the latter character. It follows that while some of the telephone research is specific, there is also another portion which is of the most fundamental character as regards the sciences upon which the telephone art is based.

After any research program has been satisfactorily concluded the proper standards in regard to systems, equipment and apparatus are established by the Department of Development and Research and these are then specified for their proper uses in the Associated Companies by the Department of Operation and Engineering.

Previous to 1907, three laboratories or departments of development and research were maintained in the Bell System, one by the American Company at Boston, one by the Western Electric Company at Chicago, and one by the Western Electric Company at New York. In 1907, in the interest of economy and efficiency these were consolidated so far as laboratory and experimental work was concerned into one unit in New York. It is this unit which has recently been given a corporate form and designated the Bell Telephone Laboratories, Incorporated. The Laboratories are owned jointly by the American Company and the Western Electric Company, the expense of operation being divided according to the nature of the work done.

The recent incorporation of the Bell Telephone Laboratories as one of the group of companies forming the Bell System offers an appropriate occasion for describing in some detail this highly developed research organization. As indicated above, its functions, while distinct from those of the engineering and development departments of the parent company, articulate with them in all respects. The research problems handled in the Laboratories are primarily physical and chemical in nature but work in many other fields of science is constantly in progress and the charter of the company has been very broadly drawn to recognize both the present diverse nature of telephone research and its inevitable future ramifications.

The Laboratories comprise a technical personnel of about 2,000 persons,—highly trained scientists, engineers and their assistants. This number is exclusive of the large groups of scientists and technical specialists in the engineering and development departments of the American Company.

So large a laboratory staff, adequately supplied with the best equipment, provides an exceptionally powerful instrument of research. It is a contribution of our day, and especially of large industrial enterprises, to the advancement of science. It has been developed in response to the need for practical application of research, and is indispensable for carrying forward such concerted programs of investigation as the advancement of the telephone industry, for example, demands. The large laboratory, working to a single end, as contrasted with the individual worker, seems to present a definite stage in an evolutionary sequence. In it the many highly trained individual minds are fused into one composite mind. Some day it will be possible to state the gain in effectiveness which such a closely knit association provides, but in the meantime there can be no doubt that the gain exists. The purpose of all organization lies in the fact that the efforts of a group of people working together

in harmony toward a given end are much more effective than the same people dispersed and each laboring as a unit unrelated to the others. From this point of view the Bell Telephone Laboratories have in themselves the benefits of organization, but the gain is doubly marked, since they in turn are a working branch of a larger system, the whole of which is functioning toward a single end.

In America, the telephone is an institution of the people. Nowhere else is the service so nearly universal in the extent of territory covered, nowhere else is it so good, nowhere else is it so generally used and its use increasing so rapidly. The number of telephone calls completed last year was upward of twenty billions. Even at this, there is no sign that we are even approaching the point of saturation in the use of the telephone. The daily telephone traffic at present represents, on an average, one call by one out of every two persons in the country, and this use will increase steadily.

To care for the demands of the future, the size and complexity of the plant of the Bell System must grow steadily. Moreover, it is our ideal to work for constant improvement in apparatus, in methods, and therefore in service, until in the ultimate, any subscriber can reach any other subscriber, even if thousands of miles away, as readily and promptly as though he were in an adjoining room.

The future possibilities of the telephone appeal to the imagination. Growth will always bring new problems as it has in the past—problems as numerous and vital as at any period in our development. The multiple switchboard, the underground cable, the long overland toll cable, the carrier current systems, are our answers today to the demand for telephone service. We smile as we view a little fifty line switchboard of 1880 in the light of the 10,000 line board of today, but a steadily increasing demand means that we are even now in the midst of rapid progress. Increases in the size of the telephone plant

will always necessitate new ways of achieving old ends as well as warrant the introduction from time to time of new types of service. To meet these changing situations the one satisfactory course to pursue is that of development and research based on accurate studies and analyses of operating conditions.

The present-day complexity of the telephone plant is such that very few problems involve experts in but a single field. Improvement at one point usually opens up the possibility of improvement at other points and to take full advantage of such opportunities calls for centralized engineering and development groups who are at all times closely in touch with field conditions. Thus, transmitter and receiver tie to local and toll circuits, to central office switchboards, relays and signaling equipment, to telephone repeaters, to superposed telegraph and carrier facilities, until a single pair of wires with its associated equipment may represent the investment of more than a million dollars, and an improvement contemplated in one element may echo back and forth through the plant to such an extent that hundreds of experts in different departments are needed to decide the best procedure.

W. S. GIFFORD.

Bell Telephone Laboratories, Incorporated

THE Bell Telephone Laboratories is a new name for an essential organization in the Bell System. As the Laboratories become better known and better understood their function will be facilitated. In this brief exposition of the Laboratories some of the important features of their operation will be described.

Two Broad Physical Problems of Communication

In broad classification the activities in the Laboratories are concerned with the two fundamental and inherent problems of electrical communication: namely, that of the electrical transmission of intelligence and that of switching and controlling the channels for such transmission. In the functionalized organization by the American Telephone and Telegraph Company of its continuous program of development and research there was instituted in the Laboratories activities which have resulted from time to time in important and now well-known developments in physical principles and in the apparatus or system embodiment of these principles. And all the activities of the technical staff of the Laboratories may be considered to have been undertaken in the solution of present or prospective phases of one or the other of these two main problems, or to have been either preliminary to their investigation or by-products thereof.

In the development of transmission systems the effective, and at times determining, contributions of the Laboratories have been evident in carrier current and radio systems, in telephone amplifier and repeater systems, in loading coils, in printing telegraphy and high-speed telegraphy, in duplex cable and in transoceanic submarine cable, in the transmission of pictures, and in many other instances which readily come to the mind of one skilled in the communication art.

As results of investigations basic to the problem of transmission there have been important contributions in the field of electronic physics, including not only thermionics which is basic to vacuum tube development, but also X-rays which are not so obviously important. New substances have been originated of which the iron dust material, for the cores of loading and repeating coils, and the magnetic substance, Permalloy, are well known illustrations. Fundamental studies, in the nature and characteristics of speech and the sensitivity of the human ear and its range of audition, have found application beyond the nominal limits of telephony and are today furnishing basic information to physiologists, aurists, psychologists, and students of phonetics. New vibrating systems and methods of actuating them have been devised and are finding use in loud speaking receivers or in horns where the vibrations of columns of air are controlled by proper design. Such developments have made possible also the public address system which is such a serviceable adjunct to wire or radio communication and meets a peculiar need in banquet halls and auditoriums. Results of transmission developments have been of recognized importance in the communication or signaling equipment of our Army and Navy. Other developments of these studies are illustrated by the power-line carrier-current system which permits the transmission over a high-voltage power line of telephone messages between substation operators.

In the field of switching and controlling transmission channels the contributions have been evident by thousands of refined devices and arrangements, familiar to those acquainted with inside telephone plant, by improved designs or circuits which result in smaller size, decreased annual charges, increased reliability, and greater speed and ease of operation or maintenance. From time to time the system studies have culminated in complete central-office systems, as most recently in that of the panel-type machine-switching system. Each advance in transmis-

sion, as well as the continuous increase in public patronage, has laid an increased burden on the designers of systems and of control equipment which has been met promptly, or even anticipated by suitable apparatus developments. If it had not been met the present extensive use, for example, of repeater stations and of carrier-current systems for multiplex telephony and telegraphy would undoubtedly have been delayed or uneconomical. Many of these investigations also have been of service in Army and Navy equipment. In the fields of transportation and of power transmission respectively, these developments have resulted in systems for train dispatching and for the remote indication of the operating conditions at distant substations.

Although it is possible to classify the activities of Bell Telephone Laboratories as has been done above, in terms of the two major technical problems of electrical communication, such classification obscures the peculiar research organization which has been evolved for the efficient coordination of its many-sided approach to these problems and may even tend to emphasize certain developments at the expense of others, equally fundamental and economically necessary, which proceed continuously and have a steady and continuous but less spectacular effect upon the communication art.

Functional Organization

In its functional organization Bell Telephone Laboratories divides into two main groups, the first of far the larger size concerned with research, development and engineering investigations, and the second, with the commercial operations of the company and the rendering of service to the first mentioned group. In the second group fall those activities of the maintenance of the buildings, and the operation of its efficient and well equipped model shop: the purchase of supplies and equipment; all accounting and auditing; estimates and cost studies;

commercial relations with other units of the Bell System; an extensive library service with translators and bibliographers; the maintenance of correspondence files; transcription, photograph, photostat, and blue printing services; the assembling of technical information; the maintenance of the historical museum with its extensive and well ordered collections of apparatus covering almost fifty years; personnel activities, including education, employment, and medical service; and the bureau of publication.

The larger group of the Laboratories numbers some two thousand members of the technical staff. Excluding for the moment certain staff engineers, concerned with commercial developments and the exploitation of the electrical stethophone, the audiometer, the artificial larynx, and other by-products, the technical staff is divided into five main groups. One of these is concerned with patents and it is the function of this group to insure adequate patent protection for the ideas and developments of its associates.

The remaining four groups are known by the terms: Research, Apparatus Development, Systems Development, and Engineering Inspection. The activities of these four groups are, however, so closely related and so harmoniously coordinated, involving as they do the informal exchange of considerable information between members of the various groups, that the contributions of the respective groups frequently overlap and represent cooperative rather than individual activities. Certain broad lines limiting the activities of the groups are, however, implied in the names mentioned above, and are adhered to in the organization and coordination of their activities. It is the general function of the research group to be concerned with the development of physical principles; of the apparatus group with the embodiment of these principles in commercially designed apparatus suitable to perform desired functions in complete systems; of the

systems group to devise new or improved systems and assemblies of equipment; and of the engineering inspection group to insure by studies and development of inspection methods that the manufactured embodiment of the work of the other three groups, as finally delivered or installed for the telephone customers of the Western Electric Company, shall not have lost between its conception and its commercial utilization any salient contribution of these other groups.

This grouping of the work of some two thousand engineers and scientists into the four divisions just mentioned and attaching a name to each can give but an imperfect idea of the varied scope and importance of the activities. To attempt much more would require a lengthy exposition. To attempt by illustration to explain more fully the work included under these four headings might give undue prominence to the types of work in which some scores of engineers were engaged at the expense of the hundreds engaged in related and equally important work. Illustrations may be ventured, but these should be considered for the point of view and method of attacking problems. In each only a single high point can be disclosed in the present condensed exposition.

Illustrations of Problems and Methods

Consider, for example, the method of those members of the inspection engineering department who deal with such a piece of apparatus as the carbon button transmitter. Of this, some hundreds of thousands are manufactured each year. If the specifications, manufacturing tolerances and the like should be so placed as to admit to commercial service imperfect instruments even to a very small percentage of the total number manufactured, the damage to the telephone companies would be disproportionately large. On the other hand, if these limits are set too conservatively and result in the rejection of an appreciable percentage of the manufactured product,

then the cost and efficiency of manufacture are uneconomical. It is obviously impracticable to give to all of some two million transmitters a year a complete transmission laboratory investigation. A method of spot testing and checking must, therefore, be employed and a small part of the manufactured product intensively studied. What, however, are the relations between the part of the product so studied and the total part manufactured is a question of the mathematical theory of probabilities analogous to but as complicated as the problems met by life insurance actuaries. Fundamental studies of a theoretical character and careful and exhaustive analyses of large volumes of data are required in the consideration of these and related problems.

For a single example of the multiplicity of problems attacked by the research group consider the thermionic problem of the emission of electrons from a filament such as is utilized in a vacuum tube. In our modern theories the physical constants of filament materials are indications of the possible behaviors of the infinitesimal electrons of which the materials are composed. Such a study, therefore, as that of determining the relation between the total thermal emissive power of a metal and its electronic resistivity is one which is broadly fundamental to our Bell System applications of thermionics. The relation of such investigations to telephonic application are sometimes indirect and the investigations may serve merely to fill out a gap in existing scientific knowledge, on which broad knowledge, however, future developments must be based.

Of the work of the system group each development must fit with practical economy into the present highly coordinated telephone plant as well as anticipate the plant of the future. Manual and machine switching systems, local and long distance systems, circuits, power supply, and equipment, all present closely related or interdependent problems. Any development may later

contribute to some other desired advance. For example, when there was presented by the American Company the problem of automatically insuring that no two toll circuits, which needed an intervening repeater, should be connected by the intervening operator without a repeater, other recent developments were looked to for contributions. By utilizing some of the apparatus and methods recently developed for machine switching, suitable circuits and equipment were devised. Toll lines may now be equipped automatically to select, from a bank of repeaters, an idle repeater whenever they are connected to other toll lines of such transmission equivalents that a repeater is required.

In many of their problems the development groups of systems and apparatus are closely related. What a system will do is largely determined by the apparatus but the requirements imposed upon the apparatus are determined by the desired or projected system. Relays, for example, must operate for certain minimum or limiting currents which are dependent upon the circuits of which they are a part and upon the voltage range of the power supply at central offices.

When such limits are determined the problem of design becomes one for the apparatus development group. But such problems are continuous so that there is always going on a continuous program of fundamental investigations and designs. What is true of relays is also true of all the other pieces of equipment which enter into the telephone plant whether desk sets, plugs and jacks, repeating coils or condensers.

In each case fundamental studies are always in progress. Materials are investigated not only to determine new possibilities but to be informed of variations which may occur in materials already in use. New methods of measurement and investigation are developed and general relationships are established between such factors as: the operating power requirements, the size, the materials, the manufacturing conditions, factory adjustment and its

tolerances, and the annual cost figures. The latter, of course, are contributed by those engineers of the American Company who are expertly concerned with the plant utilization of the particular piece of apparatus. The steady development of the "E" type relay, of which some four million a year are manufactured, is but one example of the result of such continuous and fundamental investigations.

The Personnel of the Laboratories

The work of the Laboratories may be analyzed, as has been done, into the two main physical problems of telephony, or into those functional divisions which have just been illustrated. But neither the recognition of a problem nor the organization for its solution can be effective without a suitable working force, adequate executive leadership, and a group interested in a common field of work, with an *esprit de corps* which stimulates and rewards their best endeavors. For its peculiar problems there has been evolved not only the present functional organization, but also a remarkable corps of investigators whose individual interests and abilities are in part responsible for the formation of the organization itself.

The technical staff of the Laboratories has been broadly recruited over a long course of time. In the training, experience, and point of view of its individuals, it is adequately qualified for its large variety of tasks. Careful selection in employment and the further natural selection of experience have both been effective in producing an organization which is unique in the scientific productivity of its atmosphere. There is an atmosphere in which the technical interests of the various individuals are merged by constant diffusion like the different gases of our physical atmosphere. The outstanding characteristics of the individuals are their creative instinct and their capabilities for effective cooperation and helpful leadership.

To this scientific atmosphere there contribute men of widely different experiences. Some have grown up in the atmosphere of the Laboratories; others, fewer in number, have entered from other industrial work; and a large number directly upon completion of technical school or graduate school training. Some acquired their early telephone experience in the manufacturing organization of the Western Electric Company in the days before the formation of the Laboratories when engineering, manufacturing, and the field operations of installation were not so highly functionalized and separated. Others have come to the Laboratories with special experience in the operating telephone companies or the American Company, and have brought with them a practical familiarity with operating requirements and that resolve for a high character of public service which has always distinguished the operating departments of the Bell Companies. A considerable number has come from academic research laboratories and from teaching duties. Originally classified as physicists, chemists, mathematicians, or engineers, they have so broadened and profited by the ideas and technical experiences of each other that these more restricted terms no longer apply, but only the broad term, "member of the technical staff of Bell Telephone Laboratories."

JOHN MILLS.

NOTE—Mr. Mills is Director of Publication of the Bell Telephone Laboratories, Inc.—*Editor.*

Our Timber Problem*

LAST November there was held in Washington, D. C., under the auspices of the United States Department of Agriculture, a National Conference on Utilization of Forest Products. The principal aim of the Conference was to bring before the nation the vital necessity of reducing wood waste. The occasion was an important one. The Conference was addressed by the President of the United States, two members of the Cabinet, the Chief of the United States Forest Service and many others. These addresses received wide publicity. More people than ever before now know that prompt and vigorous action is required to overcome, as far as possible, a growing shortage of wood. One of the most important steps to be taken, on a national scale, is the dissemination of knowledge of the best practices in the economical utilization of wood and the immediate adoption, to the fullest extent that is practicable, of these methods by the vast network of wood-using industries of the nation. Another important step is to promote scientific research directed toward technical improvements leading to practices not now economically feasible. It is therefore particularly appropriate for us, at this time, not only to consider the existing timber situation in the United States but also to review briefly what the Bell System is doing about it.

The Existing Timber Situation

When the early settlers swept westward across the United States, they found two vast primeval forest regions. From the Atlantic Coast to the Great Plains extended the Eastern forest region, stretching from Canada to the Gulf of Mexico. This region comprised about five-sixths of the original total forest area of the United States.

West of the Great Plains, beginning in the foothills of

* Résumé of a talk before a group of officers of the Western Electric Company, January 2, 1925.

the Rocky Mountains and extending to the Pacific Coast, was the Western forest region, stretching from Canada to Mexico and comprising about one-sixth of the original total forest area.

In the Eastern forest area more than ninety per cent. of the original growth of timber is gone. The Western forest area is relatively less depleted, but nearly fifty per cent. of its original growth is gone. Considering both the Eastern and Western forest regions, we have left, of the virgin forests through which the pioneers blazed their way, only one-sixth in area and less than one-third in bulk of timber. The difference between these figures is chiefly due to the greater size of the trees in the relatively less depleted virgin forests of the West.

Much of the early cutting of timber was to clear the land for agricultural purposes, but the fact remains that fully one-quarter of the forest land which has been cut and burned over has become barren and useless. A considerable part of the remainder is producing second growth, so that, in the United States as a whole, there remains today a little more than one-half the original forest area.

It must be borne in mind, however, that the depletion of two-thirds of the original timber resources of our country has not been uniformly spread over the three centuries since our forefathers came here. We have cut most of our timber in the last seventy-five years.

What is the outlook for the future? There is left, according to the estimates of the United States Department of Agriculture, about seven hundred and fifty billion cubic feet of timber. This is being drawn upon to the extent of about twenty-five billion cubic feet each year. To offset this drain, our annual timber growth is about six billion cubic feet. Our annual deficit of nineteen billion cubic feet is a draft against our capital resources. We are using up our timber four times as fast as it grows. If nothing is done, two or three generations more will

witness the practical exhaustion of our existing forests and we can rely to no large extent on imports from other countries.

What can be done to improve the impending situation? There are four things to be done:

(1) Promote forest growth.
(2) Reduce fire losses.
(3) Use substitutes for timber.
(4) Increase the efficiency of use of forest products.

Promoting Growth

Throughout the country there is a widespread and increasing movement to promote reforestation, but so much time is required for a tree to mature that we must inevitably face many years of diminishing supply before reproduction will offset the impending shortage.

Natural reproduction must be the chief means of attaining the sustained annual output needed to meet the reasonable demands of our growing population and to maintain our flourishing industries. The direct planting of new trees upon land not now bearing timber offers little prospect of satisfying this need. At present about 36,000 acres are being planted annually with new trees. Even though this planting were increased till it exceeded the tenfold greater area now being planted annually by the Japanese, little impression would be made upon the 250,000,000 acres in the United States which are best suited for growing timber and upon whose increased production under intelligent control we must largely depend for our timber before a half century has passed. This acreage consists chiefly of cut-over forest land which, without much planning or control, is now reproducing trees but in a relatively inefficient fashion.

Reducing Fire Losses

As nearly as can be determined, the amount of standing timber destroyed by fires each year ranges from half

a billion to one billion cubic feet. This figure, however, inadequately represents the loss, for the reason that young timber does not show a big volume in cubic feet. While recent legislation authorizes our Federal agencies, in co-operation with the States, to establish systems of protection against forest fires, some losses from this cause are inevitable, and, at best, the elimination of a large proportion of the fire loss will fall far short of bridging the gap until reproduction begins to make itself felt to an important extent.

Use of Substitutes

As to the use of substitutes, the question is one of economic balance. As the cost of timber advances with relation to the cost of substitutes, the latter will be used more and more extensively so far as is practicable.

More Efficient Utilization

We are therefore forced to turn to more efficient methods of manufacturing and utilizing forest products as offering the most effective means for averting, as far as possible, the timber shortage that confronts us.

What are the opportunities in this direction? The United States Forest Service estimates that a saving of between twenty and twenty-five per cent. of the present drain on the forests could be realized if the best practices and knowledge available at the present time were put into effect to the fullest extent that is economically feasible.

Present losses and wastes occur from a large variety of causes. In lumbering, many trees are shattered in felling and there is a lack of utilization of stumps and tops. In sawmills, on the average, forty-five per cent. of the volume of the log is lost in bark, sawdust, slabs, edgings and trimmings and culls due to mismanufacture. Another cause is lack of care in seasoning, resulting in undue checks and cracks, loosening of knots, warping,

splitting, twisting, etc. Then there are the wastes and losses which occur in the production of finished articles from lumber and dimension material, the failure to utilize short lengths and odd sizes of lumber and the losses from decay both in the storage of timber and in structures made of timber.

Timber Conservation in the Bell System

With this picture before us, let us briefly review our practices within the Bell System to determine how effectively we are performing our part in the conservation movement by efficiently utilizing the forest products which we employ.

For many years economy in the use of timber has occupied a prominent place among our research and engineering problems. The Bell System is far removed from the class of the largest users of forest products. While it is impracticable to estimate very closely the annual amount of our purchases of wood in one form or another, it is safe to say that our use of forest products in the Bell System is well within $15,000,000 a year. In contrast to this figure, it may be noted that the railroads of the United States expend annually for lumber nearly $100,000,000, for ties $125,000,000, and for other forest products, such as poles and posts, $8,000,000.* Directly and indirectly, the railroads are said to consume about one-quarter of the annual amount of timber cut from our forests.

In considering our use of forest products the item of poles and crossarms looms large in the minds of many of us and yet it is a fact that the value of our purchases of paper considerably exceeds the value of our purchases of poles and crossarms. In much of this paper, such as newsprint for directories, and the paper used for traffic tickets, envelopes, wrapping purposes, etc., wood pulp enters to a large extent.

* Railway Age, November 22, 1924, p. 952.

The principal uses of forest products in the Bell System may be considered under three heads:

(1) In the outside plant, in the form of poles, crossarms, insulator pins, guy stubs, anchor planks, wood conduit and other parts.
(2) In paper, used for directories and other purposes already mentioned.
(3) For crating and boxing the output of the Western Electric Company's factories and the materials, apparatus and supplies distributed from its warehouses scattered throughout the United States.

Wood is also employed in telephone switchboards, subscribers' wall sets, telephone booths and other products, as well as in buildings, but the volume of consumption in the three principal classes which I have mentioned is so large, compared with these minor uses, that we can well restrict our discussion to these three subjects.

Outside Plant

The poles already in the plant of the Bell System are divided between the different species of wood approximately as follows:

Eastern Cedar	49 per cent.
Chestnut	28 per cent.
Western Cedar	14 per cent.
Creosoted Yellow Pine	5 per cent.
Miscellaneous	4 per cent.
Total	100 per cent.

Our annual pole requirements run from 600,000 to 700,000.

Poles attain the maximum degree of efficient use of the volume of timber contained in the tree. Where a tree grows in a forest stand, and not in the open, large live branches are not encountered until near the top of the tree and the point where the large branches begin can usually be made the top of the pole.

While it is true that the stocky poles needed for the heaviest telephone lines must be obtained by cutting off the tops of trees which would normally make longer poles, the top cuts are, in such cases, capable of being utilized to a considerable extent for short poles or posts. Many of our short, light poles are top cuts from a tree trunk the lower part of which is used for other purposes, such as railroad ties or saw logs.

We use large quantities of poles of species of timber for which there is not a heavy demand for other purposes.

Eastern cedar, for example, does not grow to sizes that are attractive from the lumbering standpoint, and while this timber has great durability in the ground, it is not much used for railroad ties, chiefly on account of its softness. Chestnut has never found much favor for railroad ties and does not occupy a high position in the general lumber market.

Western cedar, in the sizes which we use for poles, is not in great demand for other purposes except piling, for the reason that the larger trees satisfy the demand for cedar lumber and for shingle material. Southern yellow pine is the only principal pole timber which has an important standing in the general market for wood products and, in this case, our use is largely confined to tree trunks too small for the other varieties of products and to top cuts where logs suitable for other uses are taken from the lower part of the tree.

Our most striking contribution to timber conservation, so far as poles are concerned, has been our early application of preservative treatments and our research work in studying the actual life extension obtained by different preservative materials and processes. Engineers outside the Bell System have expressed themselves as being much impressed by the value of the results we have obtained from our comprehensively planned and continuously executed series of tests covering a period of more than twenty-five years.

We began to use creosoted yellow pine poles as early as 1897 and their use has grown to an annual purchase of over 150,000. This type of pole should last from thirty to forty years. Twenty-five years ago we made several experimental installations of surface treated cedar poles, the preservative being applied with the aid of brushes and extending up from the butt of the pole to a point a foot or two above the ground line.

About twenty years ago we started our first service experiments on open tank treated chestnut and cedar poles. Ten years ago we began experimentally brush treating, with creosote, poles in place that were then ten years old. The substantial commercial development of the open tank treating process in the United States has been based largely on the results obtained with poles treated by us in these cooperative experiments with the United States Forest Service twenty years ago.

With cedar, on account of the difficulty of forcing creosote through the outer layer of wood, we now employ a method for perforating minutely the surface of the pole that is to be treated, thus making all parts of this section of the pole accessible to the longitudinal penetration of the creosote.

Since the extensive spread of the chestnut blight, beginning about 1910, we have been using blight killed chestnut as extensively as possible for poles. Wherever practicable these poles now receive an open tank butt treatment with creosote.

At the present time, fully ninety per cent. of the poles being placed in the Bell System plant are receiving preservative treatment of one kind or another.

The saving in annual charges on treated poles and crossarms already in the Bell System plant will amount to nearly a million dollars for the year 1925. It is estimated that the saving in annual charges due to the treated poles and crossarms already in the plant will

amount to about twenty-five million dollars within the life of these poles and crossarms.

In various parts of the United States the Bell System is now seeking to make such use as is possible of local timbers for poles. The results of experiments with butt treated poles recently led to the purchase of several thousand lodge pole pine poles to be butt treated and used in Colorado and adjoining territory. Lodge pole pine does not usually reach large sizes and it grows rather slowly. There are large areas in the Rocky Mountains where it grows in profusion. It can be safely used, butt treated, only in the dry climate of the Rocky Mountain area. It will require, like Southern pine, a full length treatment if in the future it should become desirable to extend its use beyond this area.

We have recently conducted extensive breaking tests on hundreds of poles of different kinds of timber for the purpose of redetermining, for each kind, the unit strength which forms the basis of our selection of the size of pole to meet different load conditions. As a result of this work we have found that we can safely raise the working unit strengths of chestnut and yellow pine to an extent which will enable us to make considerable use of smaller poles of these timbers than heretofore.

Wherever practicable, we are extending the life of existing poles by the use of reinforcing methods, which are applied when the size of the pole at the ground line has been so reduced by decay that replacement would otherwise be necessary.

Back of all this, by constantly increasing the message carrying capacity of our open wires by means of improved operating methods, phantom circuits and carrier current telephony and telegraphy, and by continually increasing the proportion of our wires that are in cable, both aerial and underground, we are keeping our pole and crossarm requirements at a minimum. The basis of our plant engineering is also kept continually under scrutiny to

make sure that the most economical sizes of poles are always being used to meet the varying plant conditions.

Paper

For telephone directories we use about 30,000 tons of paper annually, and for toll tickets and other records, more than 10,000 tons in addition. Forty thousand tons of paper is about twice the annual consumption of a large newspaper. We have given very careful attention to conserving our use of wood in this form. We have found it possible to reduce our directory paper from a thirty-two pound paper, which is the weight generally used in newspaper practice, to a twenty-eight pound paper. We have made a thorough study of type faces and have developed a style of type for directories to give the maximum legibility for a given size. We have also gone into the matter of the most economical page sizes and we are rapidly moving from some thirty sizes to two. In this work we have aimed to avoid waste in trimming and from undue margins. What we have sought to obtain is the minimum amount of paper required per name in the directory consistent with satisfactory legibility. The same care has been devoted to minimizing our requirements for paper for toll tickets and all the forms that we employ.

Crating and Boxing

Not long ago a detailed study was made by an expert from outside the Bell System of the methods employed in crating and boxing the output of the Hawthorne factory of the Western Electric Company. In his report he said: "It is very evident that much intelligent thought has been expended on the packing problem and the officials in charge of this part of the operation are to be highly commended on the very excellent methods they have developed and put in use." He concluded by stating that he did not hesitate to say that the Hawthorne

plant of the Western Electric Company was the most efficient large plant that he had ever visited.

Conclusion

Enough has been said about our principal uses of wood to make it clear, I believe, that the Bell System, although using not more than one per cent. of the forest products output of the country, has been thoroughly alive to the importance of the conservation of timber. We have been, and we are, doing everything in our power to conserve the wood that is used in our entire system. Our research work dealing with the investigation of new preservatives for timber is being actively pushed forward.

It has been estimated that at least one-third of the industries of the United States are dependent to an important extent on forest products. The question of their economical use is therefore such a vital one, not only within our industry but throughout the entire United States, that its importance cannot be overstated.

We must not relax our efforts in this direction, but rather must we, in each and every branch of our business, continue unabated our efforts to eliminate waste of forest products in our work. Whenever the opportunity affords, we will do well to encourage other users of forest products to put forth their best efforts in this direction.

FREDERICK L. RHODES.

The Development of the Transmission Circuit in Communication

OFTENTIMES while in a reflective mood one asks "What has been the most important factor in the building up of the Bell System to its present-day enviable status?" After some analysis of the problem the inevitable answer is "There is no such 'most important factor'; rather there have been many important factors and it is not easy to rate the relative importance of each."

In calling the roll of these important factors, certainly research would be accorded a place by everyone, for it has occupied a unique place in the telephone industry, and its contributions to the communication art have been numerous and conspicuous. Among these, striking examples are encountered when one considers the development of the telephone transmission circuit.

The present discussion will not go into those distinctively technical phases of the subject, calling for integral signs, hyperbolic functions, complicated circuit drawings and alternating current theory, but attention will be directed to the importance of the place occupied by the transmission circuit in the communication art and to the fundamental changes that have been made in its development from a single iron wire ground return circuit, carrying a single message, to a copper wire metallic circuit, carrying telephone and telegraph messages simultaneously, which, together with many other metallic circuits, comprise a lead covered cable. As in all general discussions, we shall not be bound by an imposing array of details, important as they are, and for the moment it will not be regarded as good form to even mention or think of them.

Pioneer Circuit Problems

In the early days of electrical communication the terminal apparatus and the connecting line were very

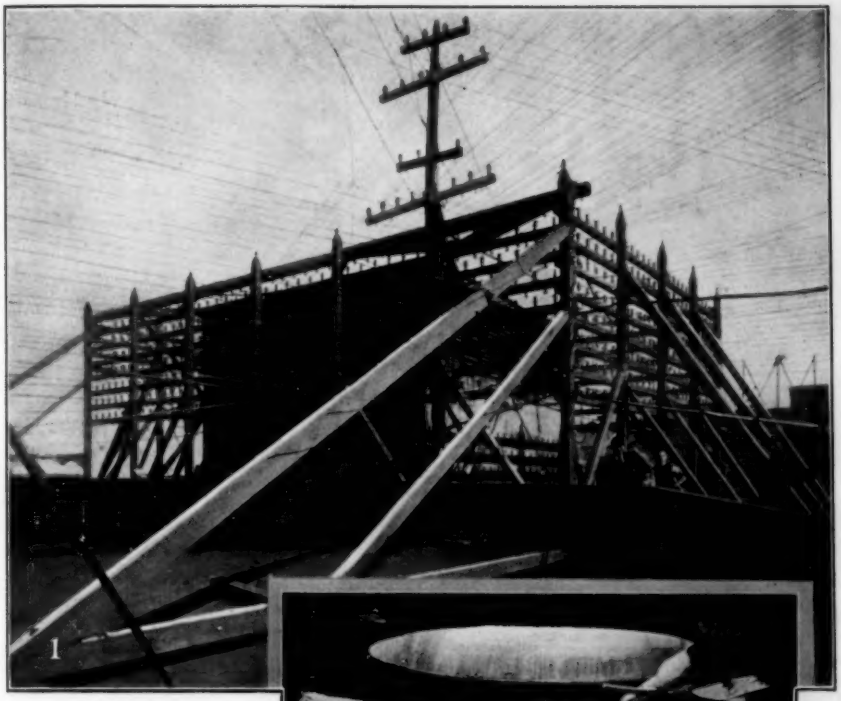
simple. To transmit by means of this simple apparatus a single message over a single wire was, for the moment, highly satisfactory. This single wire was at first an iron wire, since copper wire of sufficient tensile strength to be strung on poles had not been developed in 1876. With only the tradition of the electric telegraph to emulate, the ground return circuit was used, but what worked well for the telegraph was soon found to work very poorly for the telephone. One of these grounded telephone lines was strung on an existing telegraph line between Boston and Lawrence, 26 miles apart. Anybody listening on the telephone line could hear all the telegraph signals, and it has been said that the ensemble effect sounded like "an old-fashioned drum corps with each drummer drumming a separate tune." A line of four ground return iron wire circuits was built between Boston and Providence and, although it was possible to talk on one of them alone, a great bedlam resulted if attempts were made to use them simultaneously. It was recognized that induction was the source of these troubles. Just what induction was and how to do away with it were not generally and thoroughly understood. Someone had a theory that the voice would follow a spiral but the induction would get whipped off by following the spiral. A line from Boston to Lowell, Mass., was actually constructed, using a wire conductor having a spiral cut around it. Hundreds of induction "killers" were invented by enterprising individuals. Most of them reduced induction to some extent but they were equally, if not more, effective in vitiating the transmission of speech.

In considering these early attempts to solve the connecting circuit problem, it must be remembered that the physical, chemical and electrical sciences were not at that time able to furnish sufficient facts and information with which practical engineering problems could be attacked. It is strange, as we see it now, that the ground return circuit was used at all, but the telegraph influence was

strong and the delicacy in operation and the broad range of frequencies involved in telephony, as contrasted to telegraphy, were not appreciated. What appears easy and apparent today was not easy and apparent then. It took considerable courage to try the metallic circuit, and the successful solution of which it gave promise still had to wait for the development of hard drawn copper wire. Iron wires could support themselves on pole lines, but with them the metallic circuit still had limitations. With the coming of hard-drawn copper wire, the metallic circuit came into its own. There were still problems of crosstalk from neighboring circuits, but the classical experimental work of J. J. Carty pointed out the way to overcome these difficulties by the use of wire transpositions. In fact, crosstalk and other extraneous influences have always offered serious problems. The success of a telephone circuit is not assured until these are solved.

Growth of Telephone Business Brought New Problems in Connecting Circuits

Prior to and for some time after the above refinements were made in the telephone line, the ground return iron wire circuit rendered fair service in a number of towns. With the early difficulties of the telephone circuit fairly well solved, more lines were built here and there and the nearby separately operated exchanges began to be interconnected. Many communities became convinced of the valuable services that the telephone could render, and the number of lines within cities and those between cities became more numerous. These ever-increasing demands for telephone service presented several big problems. In the first place, more wire facilities had to be provided, and in the second place the distance over which speech could be transmitted must be increased. Furthermore, the existing wire facilities must be used more effectively. At one time there had been something of drama and romance in transmitting a single message over a single



1. Roof structure on a Boston telephone office about 1883. This structure accommodated only 1,200 lines.

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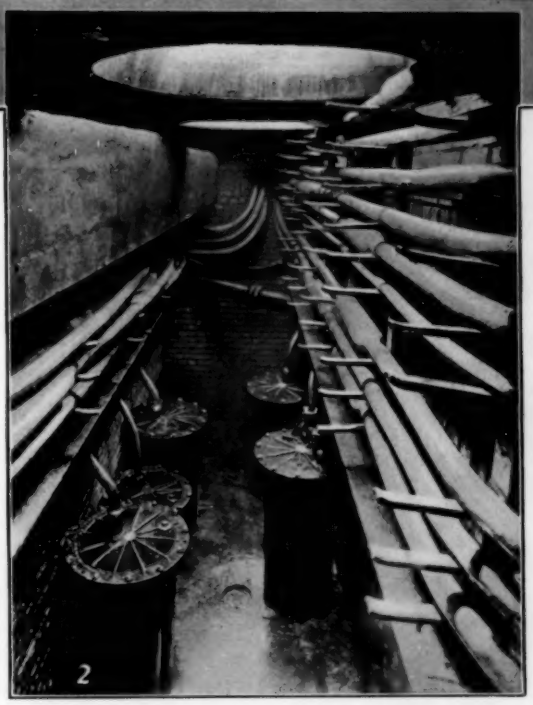
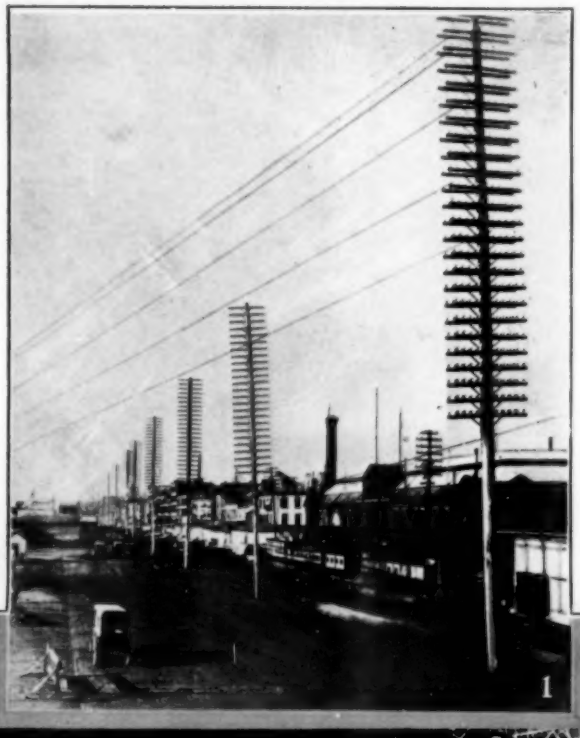


2. Modern manhole with underground cable connecting to loading coils which are housed in the moisture-proof iron pots.

A single modern cable, less than three inches in diameter, provides as great wire facilities as the large roof structure of 1883.



1. New York City pole line of 1887; ninety-foot poles, with twenty-five crossarms, and carrying a total of 250 wires.

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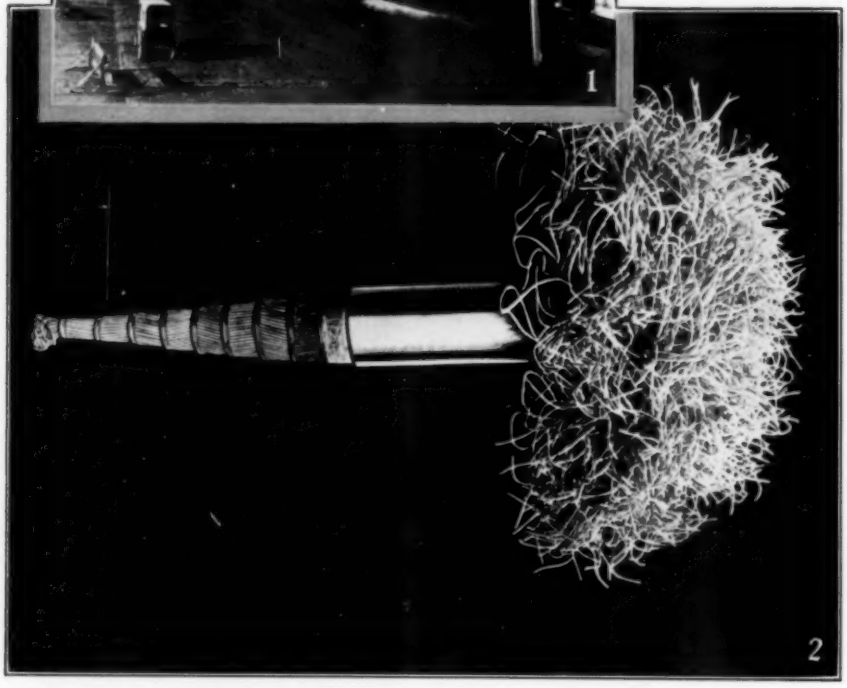
2. A single cable no larger than a man's wrist now contains 2,400 wires, or nearly ten times as many as the pole line shown above.



Underground cable systems have displaced the large exposed pole lines of a bygone day. If the telephone wires under Broadway in New York City were to be strung in the air, ten pole lines, each as high as the Woolworth tower, would be required.

circuit in a simple network of lines, but this became not only prosaic but entirely inadequate.

Cables Supply More Wires

To continually add to an already complex myriad of overhead wires by increasing height of poles, number of pole crossarms and frames on roofs of buildings did not appear to be the sound engineering solution of the problem of more wires. The solution has come in the multi-wire lead covered cable. In the beginning as few as seven rubber insulated wires, either with or without an overall protective covering, were formed together to make a cable. This style of cable was, in fact, used in connection with the ground return circuit, but the large amount of crosstalk limited its use. The next type of cable contained about 50 cotton insulated wires with an overall covering of hemp. It was drawn into an iron pipe and several sections of iron pipe coupled together. The entire length of pipe was filled with oil and sealed at the ends. At best the oil leaked out and the water leaked in and the next type of cable called for cotton insulated wires impregnated with moisture proofing compound which were pulled into short lengths of lead pipe about 100 feet long. The core was pulled into one length of pipe after another, the adjacent pieces being soldered together.

For a few years prior to 1886 there had been considerable success in making cable by extrusion of a lead sheath directly upon a cable core. In one instance this method was used to place a thin sheath of lead on a single electric light wire. Following the pioneer work a lead press, capable of making cable sheaths almost three inches in diameter, was developed. This method is now used exclusively for the making of lead cable. By 1888 a spiral wrapping of paper insulation was substituted for cotton. It was felt that a certain amount of insulating compound had to permeate between the paper insulated wires, but in 1890 some courageous pioneers installed a

dry core paper insulated cable five miles in length. The experiment was successful and from that time on, or soon thereafter, dry core paper insulated cables have been used exclusively. Step by step, gradually and steadily, cable development has progressed, and today there are available several standard types of cable which offer an effective answer to the demand for more wires. Which type of cable shall be used and when the cable line shall be built are questions that must be weighed in an economic balance.

The most common types of cable today are those using No. 24, No. 22 and No. 19 gauge copper wire. The first is supplied in a wide range of sizes up to 1200 pairs; the second up to 900 pairs, and the third up to 450 pairs. Quadded and non-quadded cables are made to individual specifications, calling for wire as large as No. 13 gauge. Special cables with various sizes of wire and various number of pairs in a single cable sheath are also supplied to fill special needs.

During the latter years of cable development, the maximum outside diameter of the cable, 2 5/8 inches, has not been changed. The possibility of replacing in an existing duct system a cable having a small number of wires by a cable having a much greater number of wires has offered opportune solutions to many critical demands for more wire facilities.

Recent figures show that there are 34,524,000 miles of wire in the Bell System. Eighty-nine per cent. of this wire is in cable, either aerial, underground or submarine, there being 70,940 miles of wire in submarine cable. Sixty-six per cent. of the total wire mileage is in underground cable.

"Loading" Increases Length of Circuits

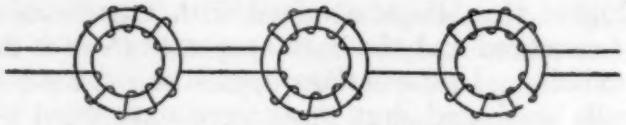
As previously pointed out, a second phase of the transmission circuit problem was the transmission of speech over longer distances. The first words ever to be transmitted electrically over a wire, spoken by Bell to

his assistant, Watson, traveled a very short distance; between two rooms in a small building. The first conversation by overhead line was transmitted on a two-mile circuit in 1876. In 1880 conversation on overhead lines was increased to 45 miles. One of the first underground cable circuit was a one-fourth mile link, laid in Boston in 1883, followed by a ten-mile link between New York and Newark, N. J., laid in 1902. By 1893 an open wire line was daily rendering satisfactory service between Chicago and New York, 900 miles apart. At this time a limit appeared to have been reached in long distance transmission, but the important work of Professor M. I. Pupin and Dr. G. A. Campbell brought about the application of the "loading" coil to telephone circuits. The incorporation of inductance directly in the telephone line at definite intervals gave such great improvement in transmission efficiency that efforts were made at once toward developing coils which would have the requisite electrical characteristics. By applying these coils to cable conductors and open wire lines of moderate size, transmission efficiencies even higher than those attained with large conductors could be secured and the heavy expenditures for the big wires avoided. In the earliest application of loading, air core coils were used, but these were superseded by the iron core toroidal type coil. In passing, it is interesting to note that the air core coils were placed in wooden cases so as to prevent energy losses due to stray magnetic fields. Following this important point in the development of the communication art, there was continued progress in open wire and cable circuit transmission culminating in the completion of the Boston-Washington underground cable, 455 miles, in 1913, and the Boston to San Francisco open wire line, 3,650 miles, in 1915. It is to be understood that these latter accomplishments came not from the use of the loading coil alone, nor from any other single device, but through comprehensive improvements and refinements in line, switchboards and all the instru-

mentalities employed. Notable among these is the telephone repeater, an important element of which is the three element vacuum tube.

Although the use of loading dates only from 1900, there were in 1911, 85,000 miles of loaded open wire circuits and over 170,000 miles of loaded underground cable circuits. A great share of this latter mileage was in the inter-office trunk cables. To "load" these circuits, 125,000 loading coils were necessary.

By 1924, the use of loading coils had greatly increased when there were 200,000 miles of loaded open wire circuits, both toll and long distance, together with 135,000 miles of loaded underground toll circuits. However, the most extensive application of loading to cables is found in inter-office trunk cables where the mileage of loaded circuits is 500,000. On December 31, 1923, 777,000 loading coils were in use, with 990,000 on December 31, 1924, and the estimated number for December 31, 1925, is 1,240,000. Something over 60% of the loading coils in the Bell System are used in the plants of the Associated operating companies.



Loading Coils Connected in Line.

More Channels Without More Wires

The third phase of the transmission circuit problem, that of obtaining more communication channels without more wires, has always been a fascinating one. In fact, so fascinating that one may readily lose sight of the matter of costs. To the engineer, however, the economics of this problem, like all the previously mentioned problems, had to be considered as carefully as the technique, for it avails nothing if it is not possible to accomplish by the new method the same or better results than were obtainable with the old at no greater cost. Obviously, if more circuits are obtained without more wires, additional

terminal apparatus must be provided. Immediately an economic balance must be sought between this additional cost and the saving accruing from less cost for wire distribution plant. This terminal apparatus has been developed which in many cases makes it economical to send more than one message either by telegraph or by telephone over a single open wire circuit. Cable circuits at the present time also carry several telegraph messages, but these are accompanied by only a single telephone message.

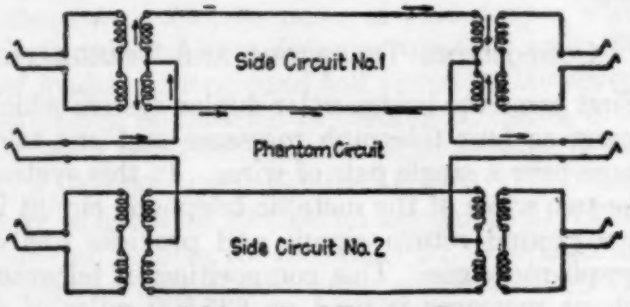
Compositing Telephone and Telegraph

First came the bridge polar duplex system which gave as many as four telegraph messages and one telephone message over a single pair of wires. In this system each of the two wires of the metallic telephone circuit is used with a ground return circuit and provides one or two telegraph messages. This compositing of telegraph and telephone messages is used on 635,000 miles of circuit, approximately one-third of which is in the plants of the associated operating companies, the balance being in the plant of the Long Lines Department of the American Telephone and Telegraph Company.

The "Phantom" Circuit

The second answer to the problem of more communication channels without more wires came in the so-called "phantom" circuit. The "phantoming" of existing circuits calls for one pair of wires to be used jointly as one wire together with another pair of wires used jointly as the other wire, to form a third circuit and so three telephone conversations are carried by four wires. This method was originally suggested about 1884, but did not come into general use until 1904. During the first years of its development, the phantom system was applied only to open wire lines. When such a line entered a city where underground cable prevailed, the phantom or third circuit

had to be carried on a separate pair of wires in the cable. In some cases where there were short lengths of cable involved, this practice was not always necessary. With the development of quadded cable which utilizes four wires in a cable as a discrete group, it was possible, about 1910, to apply the phantom method to cables. On January 1, 1924, there were 410,000 miles of open wire phantom circuits and 360,000 miles of quadded cable phantom circuits.



General Schematic of Phantom System.

Carrier Current Systems

The last step in the solution of the problem of more channels without more wires is found in carrier current systems. Here the capabilities of the transmission circuit to carry message bearing electric currents are utilized to a degree that stimulates the imagination and receives the admiration of engineers, pure scientists and laymen. By carrier current systems, four and sometimes five telephone messages, or upward of 20 telegraph messages are transmitted on a single pair of wires.

At the present time these systems are economical in a general public service communication system only when used over long circuits, in most cases more than 250 miles. If terminal apparatus can be simplified and costs decreased, it is likely that in the future carrier systems may be applied to circuits of 100 or 50 miles in length. Whether a carrier system can be justified in any given case depends

upon factors peculiar to that case. In some instances it may not be physically possible to provide additional wires over a given toll line or cable route, in which case the relatively high terminating apparatus costs may be justified.

A Carrier Current Analogue

To the layman the understanding of the functions of the essential operating elements of the carrier system may appear at first sight quite impossible. However, with the assistance of an analogy which, to be sure, must neither be taken too literally nor followed too far, a workable picture and a satisfactory insight may be obtained of the *modus operandi* of carrier systems.

Our analogy will be drawn from the everyday phenomena of light. Most people are prone to accept these without questioning their explanation and significance. Probably this situation exists because man possesses a sense of sight which is so familiar that one is likely to overlook the marvels of this gift and the opportunities for instruction it presents.

There is no more beautiful sight in nature than the rainbow; the sun's spectrum with its colors ranging from red and orange through the green to violet. The perception of these colors is readily accepted with no thought of carrier systems entering one's mind. However, as a person views the great band of colors across the sky, he is in reality making use of a carrier wave system; one which, in its fundamental features, simulates the carrier systems used to electrically transmit messages on wires.

We know that the various colors are, in reality, caused by a single kind of wave, namely, short electric waves, each color corresponding to its particular and characteristic wave length or wave frequency. These waves travel through a single medium, the so-called ether, without interference. The light paths for a dozen onlookers cross and re-cross, but each observer is unaware that the light

waves carrying impressions of color and intensity to him have encountered other light waves.

If one of the observers were equipped with a piece of red glass and looked through it at the several colors in the rainbow, he would see the red light, but all the other colors would be absent. The red glass has acted as a light wave filter; it has transmitted only the red light and absorbed the others; hence the observer will see only the red portion of the rainbow. Likewise, any other color might have been seen separately by using the proper light wave filter.

With these readily understood, simple principles and phenomena of light in mind, it would be possible to design a system of communication using colored lights at the transmitting end and colored glasses at the receiving end. Assume one had a battery of colored lights whose colors were fixed but whose intensity could be varied. By a system of multiple mirrors all the colors emitted from the various sources could be sent along a single narrow path. At the receiving end a portion of the single, narrow streak of light could, by a second system of mirrors, be sent through different colored glasses. At all times along the common path each color and the changes in intensity given it at the source are present. The narrow streak of light might appear white, that is, colorless, to an unequipped observer, but to the observer properly equipped with a colored glass, the identity of each color would be revealed and the variations in intensity observed by the eye. The observer using the red light, for example, would, through some prearranged plan, be able to interpret the variations of intensity. Red light would be used at all times by this observer and by having the intensity changed, the red light would act as a "bearer" or "carrier" of the message. Likewise all the other colors would be able, through variations in intensity, to carry a message through the same medium and along the identical path. No one color need to know that any other of the colors is "on the air" or more correctly stated, "on the

ether." Similarly, the changes in intensity of one color do not in any way conflict with those of the other colors. These changes in intensity might be called modulations of the carrier waves.

In this imaginary but easily arranged carrier light wave system, there have been five vital and essential elements:

First: Separate sources of carrier waves (in this case different colored lights) each having a fixed frequency.

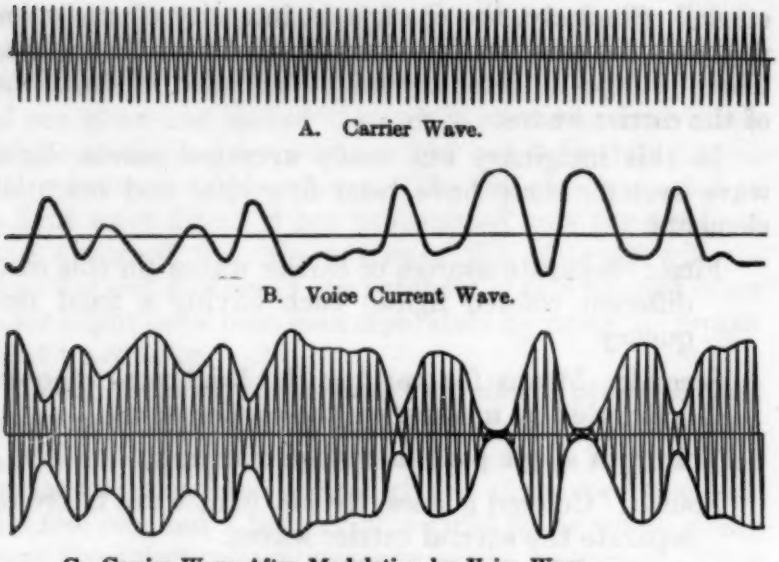
Second: Means for varying the brightness of each color, that is, modulating the carrier waves.

Third: A single path in a single medium.

Fourth: Colored glasses, that is, light wave filters to separate the several carrier waves.

Fifth: The eye which observes the modulations of the carrier waves; one might say demodulates the carrier waves.

When carrier electric wave systems are used, the above essential operating elements must be provided in an exact correspondence. The present-day, highly effective and satisfactory devices which perform these several functions have become available only after years of study and continuous experimenting. In fact, the development of these devices had to wait for new discoveries, new principles and new devices neither thought of nor dreamed of by the early workers. To get proper sources of carrier electric current, that is, an alternating current generator, which would give a high frequency of constant value; to have this generator of simple design and under simple control, capable of giving other fixed frequencies; to filter the currents each in its proper channel at the receiving end; to detect the modulation of the carrier currents when filtered and to re-design the existing wire circuits to properly carry the high frequency currents, have been some of the baffling problems.



A. Carrier Wave.

B. Voice Current Wave.

C. Carrier Wave After Modulation by Voice Wave.

Note that peaks of modulated carrier wave lie on a curve which has same shape as voice wave.

When modulated carrier wave is demodulated the voice current wave of B is restored.

Early Attempts at Carrier Current Communication

The possibility of sending more than one message over a single pair of wires obviously appealed to the research engineer when the art of electrical communication was very new. In 1872 Elisha Gray and Alexander Graham Bell separately attacked the problem from the standpoint of telegraphy. Both of these men used mechanical vibrators whose vibrations were indirect sources of electrical impulses of different frequency. The receiving apparatus also made use of mechanical vibrators which were tuned to respond to the incoming electrical impulses. The carrier waves in this case were actually interrupted to make dots and dashes. Several sets of transmitting and receiving vibrators were used simultaneously.

Gray developed this system to a high degree, but when practically installed it did not meet with the success pre-

dicted. Out of Bell's experiment came his invention of the telephone. He had had continually before him the vision of transmitting speech electrically. The concept of the fundamental principle on which the telephone works had been definitely formulated in his mind for some time prior to 1876. For the moment he was seeking to transmit several telegraph messages over a single circuit, but in the functioning of the multiple telegraph apparatus his alert perception and expert experimental sense saw the essential elements of the electro-mechanical devices which would serve as transmitter and receiver of electrical speech waves. Years later telephone engineers have come back to Bell's problem and, with the advantages of scientific development since his day, have not only successfully designed multiple telegraph systems but also multiple telephone systems.

While Bell's discovery may have been quite different from that sought at the moment, it would have passed unnoticed but for the research method being employed and the openness and alertness of mind characteristic of the true research engineer. Trained observers, of purpose and vision, systematically searching for new facts have been the necessary accompaniments of new discoveries.

The problem of carrier current communication remained unsolved until more became known about electric oscillations and waves. The oscillatory discharge of a condenser had been predicted and experimentally verified. With this source of high frequency alternating current available and with an increasing understanding of electric tuning and electric resonance, new systems of multiple telegraphy were designed. About 1893, considerable work was done on such systems, using frequencies of 200 to 500 cycles. At the same time other engineers in this country and abroad were working on the problem from the standpoint of telephony in which attempts were made to modulate high frequency alternating carrier current by the variation in the sound intensity of the voice.

Electrical oscillations were used at the transmitting end and electrical tuning at the receiving end.

The pioneers in this field made their inventions work under favorable conditions but they were too delicate, and too unreliable for practical communication service. The complications in transmitting and receiving outweighed the advantages accruing from simultaneity of messages.

Contribution of the Bell System Engineers to the Problem

The present solution of the problem had to await radically new devices which, as pointed out before, would serve as sources of carrier current at the transmitting end and filters of carrier current at the receiving end. Furthermore, means for enabling the sound waves of the voice to modulate the carrier currents and finally a means for demodulating the carrier currents. These devices, together with the development of fundamental ideas in electric wave transmission over wires and effective practices in carrier current operation are, in a large measure, the work of the research and development departments of the Bell System. The two devices which are directly responsible for the success of carrier current systems today are: the now familiar three-electrode vacuum tube and the electric wave filter.

To inquire further into the nature and function of each of these may be profitable. The vacuum tube serves as the long-sought-for source of high frequency electric waves which, with the waves from other vacuum tubes properly arranged for giving a different frequency, travel along the same pair of wires. The vacuum tube is a versatile device and is also the means by which the voice operating a second tube modulates the carrier currents sent out from the first tube. Besides performing two very necessary functions the vacuum tube offers its talents to amplify at some distant point, the carrier

currents when they have become weakened after long travel over the wires. Finally, the vacuum tube performs a fourth valuable function and is the means by which the received carrier waves are demodulated whereby the telephone receiver or telegraph instrument is enabled to give out the message intended for it.

The second device that has not heretofore been available is the electric wave filter. After putting the several carrier waves each appropriately modulated on the single pair of wires, that is, superposing the carrier currents at the transmitting end, they must be separated at the receiving end. This latter function is performed by the electric filter. Just as the colored pieces of glass permitted only certain colors to pass through them, so the electric wave filter permits one carrier wave in its modulated form to go a predetermined way and a separate carrier wave of a different frequency to go another predetermined route.

The wave filter is made up of inductance coils and condensers in various combinations. The filter is, as it were, electrically transparent to one group of carrier waves and electrically opaque to all other carrier waves.

The vacuum tube and the electric wave filter are two of the very remarkable products of research. The experimental work of Edison and DeForest in this country, the experimental work of Fleming and the theoretical work of J. J. Thomson and Richardson in England, brought the vacuum tube through the early stages of development. From the fragile, unreliable and weak device of 1912 it was later developed into a sturdy and reliable piece of electrical machinery, if this expression can be applied to an evacuated glass vessel. Where before one could hardly assign a value to the small and varying amount of power handled by the tube, the tubes now used in carrier systems are rated at about one watt while those needed in radio transmission work are rated in kilowatts. There has been no problem in electrical science and electrical engineering which has required greater skill, technical

ability and diligence than that of perfecting the three-electrode vacuum tube in which Bell System engineers have played so conspicuous a role.

The electric wave filter is the invention of Dr. G. A. Campbell of the American Telephone and Telegraph Co. Mathematical analysis of the highest order, combined with a deep and broad understanding of electrical phenomena. have made the filter possible. To create and build a . ›rkable theory is an achievement. To plan and manufacture wave filters so that they are transparent to almost any desired band of carrier waves has been a research problem in itself.

Present-Day Carrier Systems

Carrier systems are generally superposed on the important backbone open wire routes of the country. The voice frequency carrier telegraph systems operate on cable circuits and use frequencies ranging from about 200 to 2500 cycles per second. The higher frequencies up to 30,000 are used for both carrier telephone and carrier telegraph with the frequency bands allocated to the carrier telegraph occupying, in general, the lower range. At the present time there are no operating systems carrying both carrier telephone and carrier telegraph messages. This is a problem of the future.

The first carrier telephone system to be placed in commercial service in this country provided five telephone channels over a single circuit between Pittsburgh and Baltimore. This occurred in 1918.

In 1920, the first installation of carrier current telegraph equipment was placed in operation between Harrisburg, Pa., and Chicago, providing ten channels on a single circuit. Since these first installations, carrier current facilities have been added gradually and steadily. The Bell System has at present something over 38,000 miles of carrier telephone channels and upward of 155,000 miles of carrier telegraph channels. The usual practice

calls for at least four and perhaps five telephone channels in a single system.

It is expected that during the next several years carrier telephone facilities will be increased at the rate of 7,000 channel miles per year and carrier telegraph facilities at a rate of 25,000 channel miles per year.

Conclusion

"When Galileo discovered the moons of Jupiter, he was doing as useless a thing from the standpoint of its immediate applicability to human relations as he could have found to do. What did he actually accomplish? He started a train of thought. He and a few men like him got the idea that it was important to study out how nature worked." It is that study which has resulted in our modern scientific age, and so great has been man's success in turning scientific discovery to account that a strong temptation confronts him to seek knowledge because it is useful and not simply for the love of knowledge itself. No touchstone has been vouchsafed man by which he may at once determine the usefulness of the discoveries he makes. The solution to the problems of more wires, longer circuits and more channels without more wires came not in a day nor from one man, but through years of work, study and trial by many men who were "zealous in research."

J. O. Perrine.

Note—Mr. Perrine is of the staff of the Information Department of the American Telephone and Telegraph Company.—*Editor.*

Open Tank Creosoting Plants for Treating Chestnut Poles

[EDITOR'S NOTE: This is a digest of an article published under the same title in the April issue of the BELL SYSTEM TECHNICAL JOURNAL. The article has been rewritten in this abridged form to present to readers of the QUARTERLY a general picture of the subject.]

INTRODUCTION

FOR a number of years chestnut timber, because of its many desirable characteristics, has served a broad field of usefulness in telephone line construction work, not only in its native territory, the eastern and southeastern part of the United States, but also in neighboring states. In fact, as an average, about 200,000 chestnut poles are set annually in the Bell System plant as replacements and in new lines.

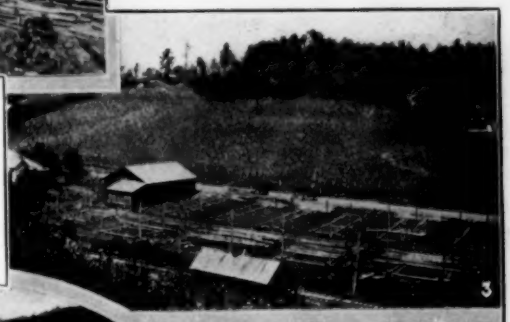
In areas which are gradually being extended from the northern part of the chestnut growing territory into the southern sections, blight is rapidly making serious inroads into this class of pole timber. North of the Potomac River practically all chestnut territories have been visited by the blight and it has in a major sense crossed into areas south and southwest of this river, where it is developing from scattered spots. While many poles are yet secured in the blighted areas, they must be cut within a very few years after becoming affected, in order to save them from the decay which destroys blighted poles after they are killed.

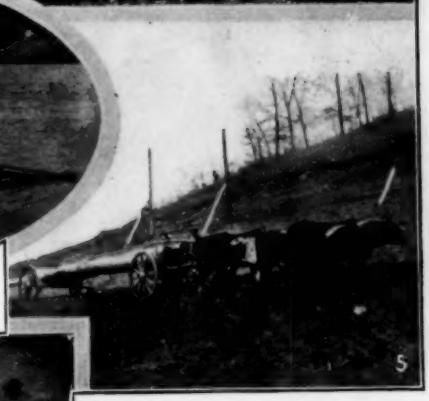
A chestnut pole lasts satisfactorily above the ground line but decays at and within a few inches below the ground, thus weakening it at a critical point. In order to protect the poles from decay at this location, the open tank creosote treatment seems to be the most satisfactory, where the facilities for applying the treatment are available. In general this treatment consists of standing the poles in an open tank and treating them in a creosote bath which covers them from the butt ends to a point

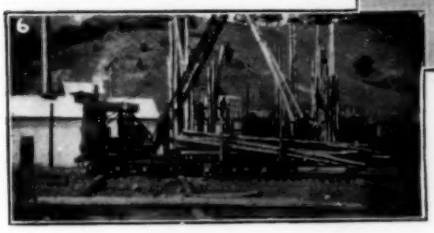
1. Land upon which Sylva plant was built.

2. Portion of pole yard at one of the smaller plants. (Tool house and creosote storage tank at right.)

3. Skid layout at one end of Sylva yard





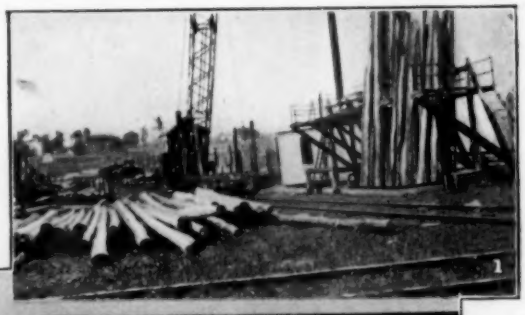


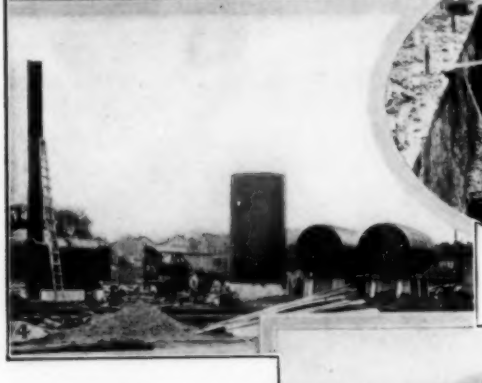
4. Four rafts of poles at Ceredo plant.
5. Pole delivery by ox-teams.
6. Unloading poles from the treating tanks to the dollies with locomotive crane.

1. Preparation skids opposite treating tanks in Nashville yard.

2. View of treating equipment at Sylva plant.

3. Excavation for treating tanks.





4. Steam boiler and oil tanks during installation.

5. General view of Natural Bridge plant in operation.

about one foot above what will be the ground line when the poles are set. The method of applying the treatment will be explained in more detail further along in the paper.

Due to the scattered locations of the chestnut timber and also to the fact that in many places this timber is rapidly being depleted by the blight, it has required considerable study to establish locations for open tank treating plants which would be convenient for applying the treatments and would also have a sufficient available pole supply to permit the operation of the plants long enough to warrant the necessary investment in them. However, suitable locations have been established and plants have been constructed which will, when operating to their planned capacities, treat about 139,000 chestnut poles per year, and the plants may easily be enlarged to treat additional quantities as the demand for treated poles develops.

These plants have been designed by our engineers and are being operated for applying preservative treatments to poles used by the Bell System.

Locating the Treating Plants

Several factors were considered in determining the proper locations for the seven Bell System treating plants which have been built. It was often possible to select a location which was admirably adapted to the purpose when considered from two or three viewpoints but which was found undesirable when considered from all of the necessary angles.

Experience of the Western Electric Company's Purchasing Department and the local Associated Telephone Company representatives, together with information from Government reports, provided the answers to several of the questions with regard to the various proposed sites. Studies upon the ground were made to settle the remaining items after a preliminary survey of the situation had indicated what locations seemed to warrant consideration.

The unevenness of the land as shown by Figure 1,

page 133a, which is typical of the many available locations studied, made it difficult to secure a comparatively level tract of the proper area and dimensions adjoining a railroad siding or at a location where a siding could conveniently be established. In fact it soon became evident in making the preliminary studies, that it would be necessary to design the various treating plants to fit the best of the available tracts.

As a result of these studies, seven plants were established and placed in operation in five states, as outlined below:

Location	Date When Plant Was Placed in Operation	Annual Pole Capacity Now	Total Annual Pole Capacity When Additions Now Planned Are Completed
Shipman, Va.....	Oct. 1922	10,000	15,000
Danbury, Conn.....	Dec. 1922	10,000	10,000
Natural Bridge, Va...	Apr. 1923	10,000	18,000
Willimantic, Conn...	Aug. 1923	10,000	10,000
Sylva, N. C.....	May 1924	18,000	25,000
Nashville, Tenn.....	July 1924	18,000	25,000
Ceredo, W. Va.....	Sept. 1924	23,000	36,000
Totals.....		99,000	139,000

It will be noted from the above table that several of the plants are not yet working to their capacities as now planned. In designing the plants, the plans were made to provide for the total annual capacities shown above. However, when they were built the initial capacities were made somewhat lower, as indicated by the table, by omitting equipment which could readily be added in conformity with the plans, later when the additional capacities would be required.

Yard Sizes

It might not seem necessary to occupy a very great area in the operation of a pole treating plant. However, experience with some of the earlier plants indicated that a reasonably large yard was very desirable because of the

number of poles necessarily carried in piles on skids in the yard both in the untreated stock and in the treated stock. In so far as practicable the poles in the various treating plants are arranged in such a manner that each length and class is piled separately. This greatly facilitates handling the poles, but requires considerable space. Ordinarily about 80 pole piles are necessary in a yard.

From four to ten acres of land has been used for each of the various pole treating yards. Figure 2, page 133a, which includes about half of a comparatively small capacity yard, shows the necessity for plenty of room for the pole piles.

Yard Layouts

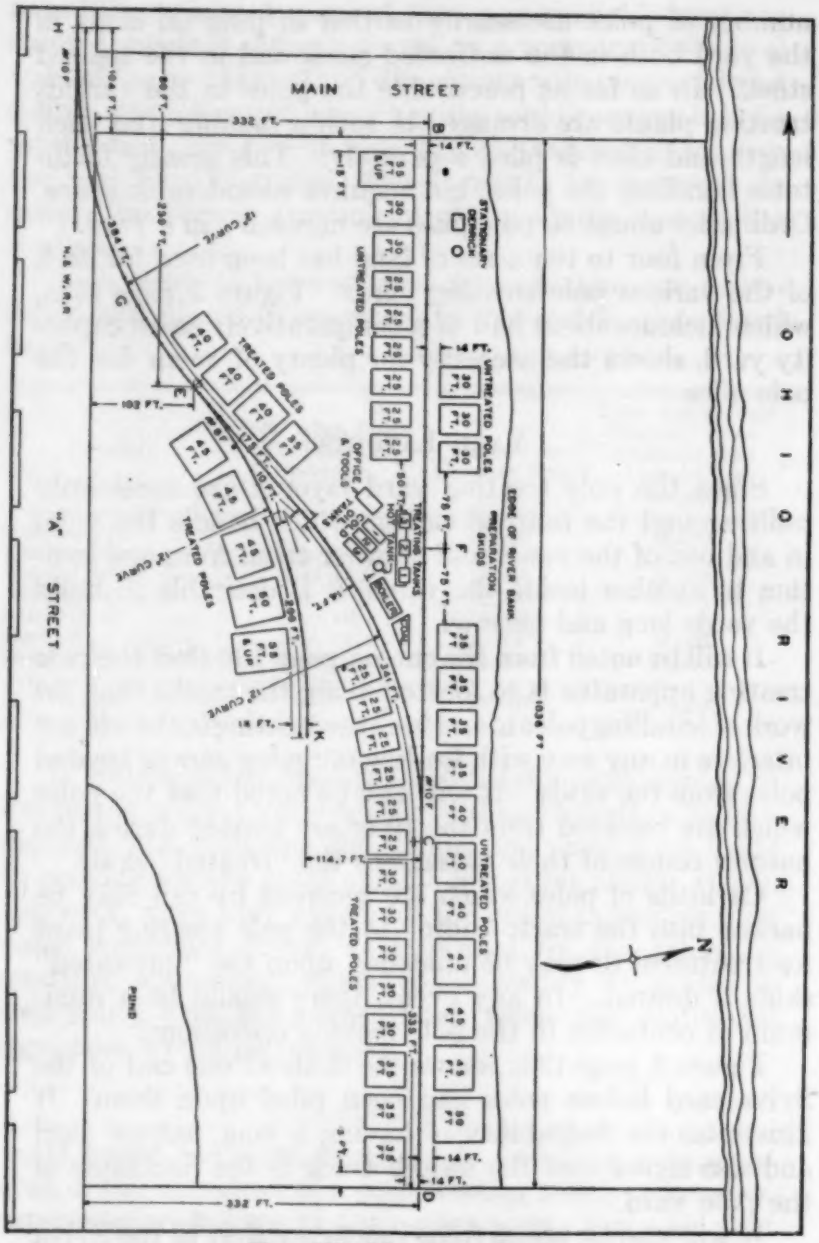
Since the pole treating yard layouts are necessarily built around the railroad sidings which handle the poles in and out of the yards and transfer them from one location to another inside the yards, it is desirable to build the yards long and narrow.

It will be noted from the cut on page 136 that the pole treating apparatus is so located along the tracks that the work of handling poles to and from the treating tanks will not interfere in any way with loading outgoing cars of treated poles from the skids. It will also be noted that the poles which are received from the river are treated during the natural course of their passage to the "treated" skids.

Carloads of poles which are received by rail may be backed into the track leading to the pole treating plant for treatment or may be unloaded upon the "untreated" skids if desired. In any event, there should be a minimum of confusion in the pole moving operations.

Figure 3, page 133a, shows the skids at one end of the Sylva yard before poles had been piled upon them. It illustrates the desirability of having a long, narrow yard and also shows that the switch track is the backbone of the pole yard.

It will also be noted from this figure that in the Sylva yard the ends of the skids are brought up close to the



Plan of Yard Layout for Ceredo.
(Each skid shown is separated into two pole piles.)

track. This is because the pole handling in the Sylva yard is done by means of a locomotive crane which runs on the track and works from the ends of the cars.

In the Natural Bridge yard, which is shown in Figure 5, page 133b, a tractor crane is used for pole handling. This unit has crawlers and wheels which operate on the narrow roadways at either side of the spur tracks. The tractor crane runs up to the side of a car to unload it. By operating at the sides of the cars a much shorter boom is required by the tractor crane than for the locomotive crane working at the ends of the cars handling the same lengths of poles.

Delivery of Poles to Plants

Various methods are used for delivering poles to the treating plants, from the locations where they are cut. In addition to the use of automobile trucks with their trailers, and to the use of horse-drawn wagons which may be seen along the road in Figure 3, page 133a, poles are delivered by railroad cars, river rafts and ox-teams.

From one to ten carloads of poles in a group arrive at the treating plants. A carload varies between 40 and 65 poles, depending upon the sizes of the poles.

At Ceredo and Nashville, where the plants are located on the river banks, utilization of the cheapest method of delivering poles to the treating plants is possible. These poles are securely tied in rafts of about 100 poles each and either floated down the rivers or handled by stern wheel, river steamboats.

Handling Poles in the Yard

It has been found that wherever it is possible to eliminate the handling of poles by man-power, a considerable economy can be realized. Less men are required for crane or derrick operation, and the cranes and derricks do the work much more rapidly.

The tractor crane which is used for pole handling in the smaller plants is operated by a heavy duty gasoline

engine and it is able to handle a 4,000 lb. load at a 15 foot radius through an arc of about 270 degrees.

In the smaller plants where it has been found desirable to increase the pole treating capacities above what could be handled by means of the tractor cranes, stiff leg derricks have been installed. However, where the treating plant is of large enough capacity to warrant the investment in a locomotive crane, this type of unit has proved to be the most satisfactory in operation.

The method of handling poles most commonly used when moving them from cars to piles and vice versa, is to lift them either singly or a few at a time, suspended from the end of the winch line, swing them to one side of the track and pile them parallel to it. Another method which is applicable, particularly to handling a 40-foot and longer pole, consists of butting the pole end against the boom of the locomotive crane and swinging it to a pile which lies perpendicular to the track.

Treatment

The following is a very brief outline of the method pursued in treating the poles and also of the results obtained.

In so far as practicable the poles are seasoned six months or more before being treated. The method of treatment consists of immersing the butts to a level of about one foot above what will be the ground line of the poles, for not less than seven hours in creosote at a temperature between 212° and 230° Fahrenheit. At the end of the hot treatment, the hot oil is quickly removed from the tank and cold oil at a temperature of from 100° to 110° Fahrenheit is permitted to flow quickly into the treating tank to the level previously reached by the hot oil. The cold oil treatment lasts for at least four hours.

During the treatment, the creosote is absorbed by the pole to such an extent that as an average, about 95 per cent. of the sapwood in the treated section of the pole is

saturated. This requires from two to four gallons of oil per pole, depending upon the size and condition of the pole being treated.

Assembly Layout

The same general features of design were followed in all the pole treating plant layouts in so far as practicable. However, the number of the different units used was varied to provide the plant capacities required.

Throughout the plant designs, careful study has been given to facilitating the handling of poles, since a considerable part of the cost of the pole treating process is due to pole handling.

Pole Racks

For supporting the poles standing in the treating tanks, it is necessary to have a very strong rack surrounding each of the tanks. The poles stand 8½ feet below the ground level. They are supported at the ends and middle of the rack by timbers under the rack platform at a height of 12 feet above the ground. At the back, the poles are supported by a timber which is 16 feet above the ground. This arrangement permits the treatment of any size of pole up to and including 65 feet in length.

Tanks, Boilers, Radiators, Steam Traps, etc.

Some idea of the sizes and arrangement of the treating tanks can be had from the excavation for them shown in Figure 3, page 133b. Each of the raised levels shown will support the bottom of a tank while the pits between will contain the steam and oil piping, oil handling machinery, etc. This is a three-tank pit with space for two tanks shown.

In order to provide dry pits for the equipment below the treating tank bottoms and also to facilitate removal of a tank from the ground in case it might need repair, it has been found desirable to build concrete foundations and walls around the treating tanks.

A few inches of space is left between the concrete retaining walls and the sides of the treating tanks. This space serves two purposes: it permits placing or removing the tanks with ease and it also provides air spaces around the sides of the treating tanks, which tend to insulate them from the ground.

Each of the horizontal cold oil tanks has a capacity of about 14,000 gallons. Tanks of this size will easily take a tank-car load of creosote each, leaving some reserve capacity for residual oil which may be in the tanks at the time the additional cars of oil are received. The tank cars ordinarily carry from 8,000 to 12,000 gallons of oil.

The hot oil tanks vary in capacity between 3,000 and 13,000 gallons each, depending upon the sizes of the plants. One hot oil tank suffices for each installation.

For these installations, a self-contained type of steam boiler was used because of its comparatively high efficiency in the sizes required and also because of the ease of installation. The boilers used vary from 30 to 80 horsepower capacity, depending upon the sizes of the plants. These boilers are of the return tubular type with the fire boxes and smoke boxes lined with keyed-in fire brick.

The water condensed from the various radiators is returned to the boiler in order to conserve its heat. Small automatic steam traps pass the water condensed in the radiators as fast as it is made, but do not permit the steam to pass. On the water side of these small steam traps, the piping from the various radiators is brought together and led to a point above the steam boiler where it is connected to a large tilting trap. The traps automatically raise the water to a receiver above the boiler and the tilting trap injects it into the boiler as fast as it is delivered to the water pipe lines by the small traps.

It is very desirable in the operation of the steam turbines that they be supplied with dry steam in order that slugs of water cannot enter the turbine chambers at

high velocities and injure the vanes. A large water trap is located above the treating tank pit at each plant to insure dry steam for the turbine which is mounted in the pit directly below it.

Oil Handling

The heart of the oil handling apparatus, of course, is the centrifugal pump which has been mentioned and which is directly connected to a 20 H.P. steam turbine in most of the plants. In some of the smaller plants the centrifugal pumps are operated by 5 H.P. gasoline engines.

The oil change ordinarily is made in from 7 to 12 minutes from the time the pump starts to remove the hot oil until the cold oil is up to the proper level. Experience indicates that no material loss in penetration of the creosote into the poles is experienced by having the treated section uncovered for this short length of time. Practically the same penetration is obtained as would be secured by keeping the poles in hot oil for the same length of time and then permitting the hot oil to remain around them until its temperature had gradually fallen by radiation to that specified for the cold oil bath.

Changing the oil instead of permitting it to cool in the treating tanks greatly expedites the treatments and consequently increases the plant capacity, which of course, results in a corresponding economy in the cost of treating the poles.

Conclusion

In this paper an endeavor has been made to cover very briefly the principal engineering and operating features involved in building creosoting plants designed specially for applying open tank treatment to chestnut poles. The treating plants which have been described, are valuable assets to the Bell System in providing concentration points where preservative treatment can be economically applied to the chestnut poles, thus becoming an important factor in the general program for the con-

servation of natural resources, by making possible the utilization of this valuable and rapidly diminishing type of timber over a considerably longer period.

T. C. SMITH.

NOTE—Mr. Smith is a member of the staff of the Plant Engineer of the American Telephone and Telegraph Company.—*Editor.*

The Growth of the Historical Collection

IT IS now two and a half years since Mr. Thayer, by opening the American Telephone Historical Collection, offered to the people of the Telephone means for the permanent preservation of the original papers and other memorabilia that carry the human story of the development and service of the Telephone and of the men and women who make up the incorporated family called the Bell System. Many Telephone people have availed themselves of this opportunity and cordially cooperated in this historical work,—not only leaders prominent in the Telephone organization and men who have borne a distinguished part in its history, like Mr. Thayer himself, Thomas A. Watson, Thomas D. Lockwood, and General John J. Carty, but also members of the families of telephone men who are now deceased, telephone employees of all grades from executives to linemen and operators, independents who have been at one time or another on the other side in telephone matters, and straight outsiders who have never been connected with the Telephone at all, except as subscribers, yet who have heard of this Historical Collection, have been interested in its inherent value, and have lent their cooperation to its purposes.

On an earlier occasion opportunity was taken to state the idea of this Historical Collection in general terms. (BELL TELEPHONE QUARTERLY, January, 1924.) Now it is desired to make some sort of report, though it can be only suggestively, to the many people who have contributed to the remarkable growth of this Collection as to what is the result thus far of their accumulated contributions. Each one knows what he has given; few realize how large and important has been the aggregate result of their combined cooperation.

CORNERSTONES OF TELEPHONY

Always the thing of most significance in this American Telephone Historical Collection will be the First Tele-

phone Patent, No. 174,465, issued, as the document states, on March 7, 1876, to Alexander Graham Bell of Salem, Massachusetts, for an Improvement in Telegraphy. By this document the American people authorized and assured to themselves as individuals all the personal benefits of direct and private electrical communication, and to themselves as a nation all the public benefits that have flowed in from the resultant general welfare.

Of very great interest also is a little purple bound notebook which has been given to the Collection, in which Thomas A. Watson entered on March 10, 1876, that same afternoon, the first intelligible sentence ever transmitted by telephone, which most appropriately was an emergency call: "Mr. Watson, come here; I want you." One of the most important letters in the history of electrical communication is also preserved here, the letter to Gardiner G. Hubbard, Trustee, and Thomas Sanders, Treasurer, whereby on May 28, 1878, Theodore N. Vail accepted the General Managership of the Bell Telephone Company and entered on that great industrial career by which he created the Bell System and made neighbors of a hundred million people.

But the Telephone has not been produced by a few deft strokes of its men of genius. The daily routine of its outstanding men has counted just as much and more in accomplishing the great achievement as their moments of inspiration; and the daily toil of the innumerable rank and file, from the beginning to the present, of whom the present active force alone numbers 350,000 employees, has counted just as much again. How can this Historical Collection come to represent, even suggestively, the human story of all this tremendous work and achievement! It must reach out for material showing all aspects of telephone work from pure research and administration to operation and accounting, and trace the story in the records of all kinds of telephone workers, whether prominent or obscure. And in all this the living element of the

personal character must be remembered. There is a little badge in the Collection which has become to a considerable extent an emblem of what it is hoped the American Telephone Historical Collection may grow into more and more. It is one of the badges of the first meeting of the Telephone Pioneers of America, in Boston in 1911. It says "Hello, Theo. N. Vail Speaking." That personal feeling we hope to elicit from the historical material and keep vivid, so that here in this American Telephone Historical Collection the telephone people of the future may always find Alexander Graham Bell, Theodore N. Vail, and all the others who have done vital work in the development of the Telephone, speaking.

Personal Collections

Collections of papers that come from some one telephone man, or that center around the work of some one man, are kept together and the collection is named after him. The first such collection to be received was the Thomas A. Watson Collection. Mr. Watson took an immediate interest in this historical work as soon as it was started and gave to it all his papers, including naturally many of great importance; he is still continually adding to it as he finds something more of interest. The Sanders family similarly have made some invaluable contributions in the Thomas Sanders Collection,—such as the checks and receipts for money that Mr. Sanders gave Mr. Bell for his experiments both before and after he invented the telephone; and the original manuscript of the one address Mr. Sanders wrote on the early days of the Telephone, scribbled in pencil on the backs of 24 of his old billheads and delivered to his neighbors of the Fortnightly Club of Haverhill, Massachusetts, on March 23, 1903.

The George C. Maynard Collection is the largest of the collections thus far received. Mr. Maynard, the pioneer of the Telephone in Washington, was himself an

indefatigable collector. About two years ago Mr. A. E. Berry, President of the Chesapeake & Potomac Telephone Companies, secured this collection and sent it to New York to form the nucleus of the Chesapeake & Potomac section of the American Telephone Historical Collection. It takes up 32 of our large special volumes with material bearing on the Chesapeake & Potomac Telephone Companies alone, and about eight volumes more on other companies. Among these papers is the inimitable series of reports of Warren Choate, whom Mr. Maynard hired in 1878 at $75 a month, payable weekly, to canvass the city of Washington for telephone subscribers. These reports preserve not only the important facts of that work, but also show us what it felt like to introduce the telephone into the national capital, or, rather, to try to introduce it. He had some amusing discouragements, as when he went to the White House and found that the President was "not in"; and when he went to Anthony Pollock, Bell's patent attorney, confident that he would appreciate the value of the telephone and order one, only to find that Mr. Pollock expected to get it for nothing and said he would see Mr. Maynard about it. But Mr. Choate succeeded in his mission in the end.

The Thomas E. Cornish Collection was given to the American Telephone Historical Collection about a year ago by Mr. Cornish himself. It is interesting in these letters and papers to see how great a part the anthracite coal mines of Pennsylvania had to do with the starting of the Bell Telephone Company of Philadelphia, and so of the present Bell Telephone Company of Pennsylvania. W. D. Sargent began his telephone work with Mr. Cornish. Consequently he appears often in the Cornish Collection. A large part of the W. D. Sargent Collection itself, thus far, has foreign associations, consisting of the complete papers of Mr. Sargent's work in charge of the Telephone Exhibit at the Paris Exposition of 1889, of which we have also the award of the Grand Prix to the American

Bell Telephone Company and the accompanying gold medal.

Echoes of the Great Ligitation

The great ligitation of 1879 is recalled in three collections. The eminent telephone lawyer, James J. Storrow, used to keep a box in which he stored up against the always possible cold and rainy day special reports and other papers with which to allay the hunger of legal emergency. His colleagues called this box "J. J. Storrow's Meat Safe." This most interesting collection of reserve material has been brought out of storage and placed in the American Telephone Historical Collection, where it retains its oldtime name of "J. J. Storrow's Meat Safe." From the other side of that great legal battle, through the kind offices of Mr. J. S. McCulloh, has come another invaluable lot of papers, the Elisha Gray Collection, turned over to us by Mr. Samuel S. White of Philadelphia, the son of Elisha Gray's old friend and backer of the same name, who appreciates with us that in telephone matters also the Blue and the Gray are now united, and who feels that the American Telephone Historical Collection is the natural and the best place for this important collection to be kept. And third, the Francis Blake Collection, which, while not directly connected with that litigation, is the collection of one of the two champions in the struggle between the Bell Telephone and the Western Union for superiority in equipment that was going on at the same time. For the Blake Transmitter, in conjunction with the original conception of Emile Berliner restored to the Bell Telephone the unquestioned control of the industry which had been gravely imperilled by the carbon transmitter of Thomas A. Edison. Within a few weeks Mrs. Blake and the son, Mr. Benjamin S. Blake, have given to the American Telephone Historical Collection five large volumes of the letters and other papers of Francis Blake.

In the early '80's, when Thomas D. Lockwood was traveling through the country inspecting telephone ex-

changes and making suggestions for their improvement, with keen appreciation of historical matters he asked the pioneers to write out for him the story of how they started the telephone in their respective cities. Gathered together in a strong binder, these personal reports of the beginnings of the telephone in sixteen cities, from Portland, Maine, to Denver, Colorado, and from Detroit, Michigan, to New Orleans, Louisiana, awaited the inception of this Historical Collection in the care of Mr. J. A. Gately, and then were entered as the first accession. They make a large and most interesting volume, an irreplaceable collection in themselves, many of the reports being written in longhand by such men as George F. Durant, E. B. Field, Sr., and Bernard E. Sunny, and illustrated by their own hand-drawn diagrams and sketches of the switchboards they devised for their exchanges.

Annual Reports and Telephone Directories

The more formal annual reports of telephone companies that have gone out of existence have their proper places here in this Collection. Among those that have been received are the reports of the Hudson River Telephone Company, given by Mr. James H. Manning, formerly President of that Company; of the New York & New Jersey Telephone Company, some of them given by Mr. J. S. McCulloh, President of the New York Telephone Company, and some by Mr. Frederick P. Lewis of the Southern New England Telephone Company; and of the Colorado Telephone Company and the Rocky Mountains Telephone Company, some given by Mr. F. H. Reid, President of the Mountain States Telephone & Telegraph Company and some by Mr. Lewis. Of the present Associated Companies that go back a long time, a complete set of the annual reports of the New England Telephone & Telegraph Company from its incorporation in 1883 to date has recently been sent to the American Telephone

Historical Collection by Mr. Matt B. Jones, its President.

The Historical Collection keeps its light always burning to welcome home copies of the early Telephone Directories. These so quickly and so easily get lost and destroyed. Among those that have been rescued is the second list of the Bell Telephone Company of New York, dated October 23, 1878. It is printed in two columns on a single strip of paper, four feet long and nine inches wide, and was evidently intended to be hung on the wall. There are no residences listed among the 446 stations. That was of course before the day of telephone numbers, but it is a classified directory. The directory of the Telephone Despatch Company, the operating company of Boston, for January 1, 1880, carries on the front cover a plea to subscribers to confer a favor by using the numbers as much as possible. The little 3″ x 6″ directory of the Connecticut Telephone Company for July, 1880, lists 549 subscribers for the State. A directory published for Cleveland, Ohio, about 1890, has the subscribers listed in numerical order only, so that if anyone called up in the subscriber's absence and left a telephone number, the subscriber could look the number up and find out who it was before calling him back.

What we should certainly call a most ambitious undertaking was the National Telephone Directory of the American Telephone & Telegraph Company for October, 1897. It listed in its 782 pages all the long distance stations in the United States connected by metallic-circuit lines with the long distance system. These were all comprised within the territory of 30 States and the District of Columbia, all east and north of a line formed by the States of Virginia, Kentucky, Tennessee, Mississippi, Arkansas, Missouri, Kansas, Nebraska, Iowa, and the Dakotas, with the exception of 17 stations in Huntsville, Alabama. It was the only national telephone directory ever attempted. Now every telephone station is a long distance station.

First Editions

Of the same year, 1897, is a little book, 4 by 5½ inches in size and of only 30 pages, given by Mr. George F. Lillis, entitled "Rules for the Government and Information of the Employees of the Traffic Department of the New York Telephone Company." It was compiled by E. F. Sherwood, Superintendent of Traffic. Present members of that department seem to feel that this little book bears the same relation to the present tome of Rules as the proverbial acorn to the giant oak. Certainly in the same class must be placed the first day's work report of the American Telephone & Telegraph Company, all told on two postcards, dated August 20, 1885, and signed one by A. S. Campbell, the head of one gang, working at Port Richmond, New York, and the other by A. G. Crocker for James Doyle, the head of the other gang, working at Mount Holly, New Jersey.

In July, 1877, Prof. A. E. Dolbear, one of Alexander Graham Bell's most worthy rivals, published a little book on The Telephone, in which, while mistaken in regard to certain facts,—the date of Bell's invention, for instance, which he gave as December, 1876,—he gave just and generous credit to his rival in many respects. This was, however, too much for the Bell Telephone Company's powerful enemy of that day, the Western Union Telegraph Company, which at once ordered that edition of the little book to be suppressed and another to be issued with the offensive passages omitted. A copy of each of these editions, the first being probably the only copy now extant, was recently given to this Historical Collection by Mr. Lockwood. He has also given the Collection a copy of his own first telephone book, "Practical Information for Telephonists," translated into Japanese by Shigenoni Katogi in 1889. Another valuable little book is Mr. Thayer's red leather pocket notebook, in which, when working for the Western Electric Company in Chicago

in 1882 or 1883, he worked out the first price scale for lead covered telephone cable.

The Barton Mortgage

Legal documents are supposed by many to be in themselves quite devoid of sentiment or of any interest. But surely the 60,000 workers in the Western Electric Company will every one of them feel a certain tenderness for the original bond and mortgage for $400 which on March 20, 1869, Mrs. Fanny A. Barton gave on her house in order to help her 26-year-old son, Enos, to purchase of George W. Shawk a half interest in the little electrical manufacturing business which later became the firm of Gray & Barton and still later the Western Electric Company. This has been placed in the American Telephone Historical Collection through the courtesy of Mr. DeWitt C. Tanner and Mr. C. G. DuBois for permanent preservation.

As has been said, "There are tears in things!" But also smiles,—witness the solemn written agreement, for which we are indebted to Mr. Frank B. Spooner, by which H. W. Pope, as General Superintendent of the Metropolitan Telephone & Telegraph Company, on the 21st day of June, 1880, contracted with A. H. Adgate of Yonkers, New York, to hire him, the said party of the second part, to manage, take charge of and care for the telephone exchange at Yonkers, recently acquired from the Western Union Telegraph Company, for the period of one month from the date thereof, and to pay the said party of the second part the sum of $10 therefor; the said party of the second part further undertaking as part of his duties to account for and to pay over to the said party of the first part all moneys received by the party of the second part during the said month. It is not specifically stated whether this included the said $10 or not.

There are many others, all testifying to the red human blood that, after all, does flow in the veins of legal papers. Alexander Graham Bell's own contract with George C.

Maynard, dated April 1, 1881, for a telephone system of seven lines connecting his home and his laboratory and the homes of several of his family offers its quiet witness to the absurdity of the story that Dr. Bell would not have a telephone anywhere near him. He did not like to be interrupted when he was engrossed in the study of a problem, either by telephone or in any other way; that was all. Who does?

Another living document is the Brazilian Telephone Patent, signed April 21, 1883, with the single word and flourish, 6 inches long, "Imperador," by Dom Pedro, in transparent Portuguese, "por Graca de Deos e Unanime acclamacao dos Povos, Imperador Constitucional e Defensor Perpetuo do Brazil," but who is more truly known among us as the great and democratic minded gentleman, the devoted ruler, the eminent amateur scientist and writer, who through his cordial interest in the young teacher of the deaf mutes of Boston was instrumental in introducing the Telephone to the scientific world in the persons of Joseph Henry, Sir William Thomson and the other judges at the Centennial Exposition at Philadelphia in 1876. Curiously enough, in his private correspondence the Emperor wrote a very small, almost delicate, hand.

Epistolary Milestones

Letters, letters, letters,—the invaluable material of biography! Was there ever a letter written that did not have its own interest and throw its own light on the mind and character of the writer? There are fortunately already hundreds of letters in the American Telephone Historical Collection. Only a few can here be mentioned. There was recently secured an autograph letter by Alexander Graham Bell, dated April 9, 1888, giving an account, with volume and page references to sources of information, of all the devices that had ever been called telephones. Written in a small, sometimes cramped hand on the two sides of a single sheet of paper and filling

the margins too, what a picture it gives of Dr. Bell's thorough, scrutinizing method of gleaning facts, noting down his references, and building up his conclusions! Of his own invention he says, "I christened my apparatus 'The Electric Speaking-Telephone' but the world has abbreviated it to 'Telephone' alone."

Another letter shows us a master mind making one of its few financial mistakes, Jay Gould on April 13, 1880, refusing to buy Telephone Bonds offered him by General Thomas J. Brady, for the courteously perfunctory reason that his hands were full but expressing the opinion that they ought to bring 75 or 80. In that he was not mistaken. They did. Maybe Mr. Gould was still feeling sore over the result of the case about which William H. Forbes wrote a long four-page letter to Chauncey Smith, the attorney, on October 21, 1879, discussing the terms to be agreed upon between the National Bell Telephone Company, of which he was President, and the Western Union Telegraph Company which Mr. Gould controlled, on November 10, 1879. In contrast with this stands a letter dated November 21, 1878, recently received from Mr. Richard T. McComas of Cincinnati, showing that R. G. Dun & Co. even at that date took pleasure in commending the Bell Telephone and attesting that they sent important items of information through it to their subscribers.

One of the most important letters thus far received was sent by Mr. Charles E. Hall of the Northwestern Bell Telephone Company. It was written by Theodore N. Vail to W. A. Leary, General Manager of the Iowa Union Telephone & Telegraph Company, December 28, 1883, and asks, now that the Telephone business has passed its experimental stage, for the facts of the mutual relations of the local exchange with the public of Davenport, Iowa, and for his opinion on the practicability of having different classes of service in the same exchange, the desirability of having resident telephones for families,

and the question of whether the rates charged could be lowered without affecting the quality of the service. In one page, in the form of asking for opinion, Mr. Vail tersely outlined the whole policy of the Company with relation to the public as it has been followed ever since.

Not only written and printed papers find an appropiate place in the American Telephone Historical Collection. Photographs of those who have done vital work in the development of the Telephone have a first place in the Collection. There are more than 280 on the walls. Pictures of notable events also belong here. Two large photographs, sent by Mr. D. P. Fullerton of the Pacific Telephone & Telegraph Company, show the final connecting of the wires of the Transcontinental Telephone Line at the State line near Wendover, Utah, on June 17, 1914, while nearby rest the two flags that were raised on the telephone pole exactly on the boundary line on that triumphant occasion.

Literally of national interest has now become the original sketch for the Blue Bell, designed by Angus S. Hibbard and authorized by Edward J. Hall, Jr., for the long distance telephone with the words, "Standard Bell. Approved, 1–5–89. Use no other form." And international in its interest, remembering the war service of the Telephone in France as well as in America, which General Pershing did not forget on the day of his retirement from the post of General of the Armies, as shown by his letter to Mr. Thayer on that occasion, is the Bell Telephone Service Flag with its 20,900 figured in blue stars on the white ground.

First-Hand Reminiscences

Finally, of all historical material, not the least valuable and sometimes the most valuable are the written accounts and personal reminiscences of those who were themselves a part of what they record. Autobiographical statements, whether in the brief form of letters like the

experiences of Capt. Wiley P. Mangum in Louisiana, or told at length like those of Mr. Thomas A. Watson or Thomas B. Doolittle, give the facts vividly, in large measure as they were lived and with the individual human standpoint of the writer. To a less extent this is also true of scrapbooks. Scrapbooks have a double value. They preserve many a statement and fact recorded in the newspapers of the time which might otherwise have been lost, and also they present vividly the interests and tastes and the point of view of the one who compiled it. But this is naturally true to a greater extent of the reminiscences. The papers of George W. Foster and D. M. Clower of Texas supply personal accounts which could be obtained from no other source. The autobiographical History of the Colorado Telephone Company by Mr. Howard T. Vaille, and the sketches being written by Mr. A. S. Campbell and published in "Long Lines," and those by Mr. Charles E. Hall in the "Northwestern Bell" are inestimable in their interest and value. Mr. A. C. Skinner of Sherbrooke, Quebec, has sent to the Historical Collection in the form of several letters a most graphic story of the career of a small independent rural telephone company, its fight with the Bell Telephone Company of Canada, and ultimately its happy merger with it.

Such is the material which has already found a safe place in the American Telephone Historical Collection. But the papers and articles mentioned are only a few examples. There are many others. The Collection has grown with remarkable rapidity, owing to the great interest in it that has been taken by telephone men and women all over the United States and Canada, and the active cooperation they have given to the work. And yet, even so, what has been gathered is but little compared to the large amount of valuable historical material that is still, as it were, on the edge of the stove and in danger of loss or destruction. It is therefore very desirable that everyone who has anything similar to the

things described in this article take advantage of the means afforded by the American Telephone & Telegraph Company for the permanent preservation of written and printed memorabilia of historical value.

WILLIAM CHAUNCY LANGDON.

Abstracts of Recent Technical Papers from Bell System Sources

Metallic Polar-Duplex Telegraph System for Long Small-Gage Cables,[1] by John H. Bell, R. B. Shanck, and D. E. Branson. In connection with carrying out the toll-cable program of the Bell System, a metallic-circuit polar-duplex telegraph system was developed. The metallic-return type of circuit lends itself readily to the cable conditions, its freedom from interference allowing the use of low potentials and currents so that the telegraph may be superposed on telephone circuits. The new system represents an unusual refinement in direct current telegraph circuits, the operating current being of the same order of magnitude as that of the telephone circuits on which the telegraph is superposed.

The following are some of the outstanding features of the present system. Sensitive relays with closely balanced windings are employed in the metallic circuit, and "vibrating circuits" are provided for minimizing distortion of signals. Repeaters are usually spaced about 100 miles apart. Thirty-four-volt line batteries are used and the line current is four or five milli-amperes on representative circuits. Superposition is accomplished by the compositing method which depends upon frequency discrimination, the telegraph occupying the frequency range below that of the telephone. New local-circuit arrangements have been designed, employing polar relays for repetition of the signals; these arrangements are suitable for use in making up circuits in combination with carrier-current and ground-return polar-duplex telegraph sections. New forms of mounting are employed in which a repeater is either built as a compact unit or is made up of several units which are mounted on I-beams, and subsequently interconnected. In the latter case the usual arrangements for sending and receiving from the repeater

[1] Presented at the midwinter convention of the A. I. E. E., Feb., 1925.

are omitted, and a separate "monitoring" unit provided for connection to any one of a group of repeaters.

The metallic system is suitable for providing circuits up to 1000 miles or more in length, the grade of service being better than that usually obtained from ground-return circuits on open-wire lines for such distances. About 55,000 miles of this type of telegraph circuit are in service at present.

Supervisory Systems for Remote Control,[1] by J. C. Field. With the great growth in power distributor systems and especially with the advent of the automatic substations with no attendant there has arose need for a supervisory system to indicate to the central load dispatcher the position or operating condition of each important power unit in the outlying stations and also to give him means to operate promptly these power units when desired.

By the turning of a key the dispatcher can open or close any switch or circuit breaker, start or stop any of the machines and receive back almost instantly a visual and continuous signal of a red or green lamp. The present systems provide in effect a key and two lamps, one red, one green, for each unit supervised mounted in easy access of the dispatcher.

Two main systems known as the distributor supervisory and the selector supervisory have been developed to meet the varying conditions of service.

The distributor system is recommended when there is a large number of units to be supervised in a given station. It consists essentially of two motor-driven distributors, one in each station, running in synchronism. Brushes on each distributor pass over corresponding segments of two sets of 50 segments at the same instant. Thus by means of only four connecting wires between the stations the control and continuous indication of 50 power units is possible.

The selector system is recommended when there is only a few switches to be supervised in a single station or

[1] Electrical Communication, Vol. 3, pp. 127-133, 1924.

in several stations located some distance apart. It consists essentially of hand operated keys to send predetermined codes of impulses to operate selectively step by step selectors at the distant stations. After the selector has operated the power unit, an auxiliary contact on this unit operates a motor-driven key to send coded impulses to operate a selector at the dispatcher's station to indicate the condition of the unit by lighting a red or green lamp. Several stations can be supervised over the same three line wires.

The dispatcher by looking at the lamps on his control board can thus tell at all times the electrical and mechanical conditions at all points in the system and has means to change the operating conditions at any substation according to the demand for power.

Telephone Circuit Unbalances, Determination of Magnitude and Location,[3] by L. P. Ferris and R. G. McCurdy. This paper discusses the effects of unbalances of telephone circuits on noise and crosstalk, and describes methods for detecting the presence of these unbalances and locating them when detected. The maintenance of telephone circuits in a high state of efficiency with respect to balance is important, since unbalances contribute to crosstalk between telephone circuits and to noise when such circuits are involved in inductive exposures. Different types of unbalances are included and their effects under different conditions of energization of the unbalanced circuit and neighboring conductors are discussed. Methods are described for determining:

(1) The general condition of circuits with respect to balance by crosstalk measurements from their terminals.

(2) The approximate location of unbalances along a line by measurements over a range of frequencies with a bridge at one end of the line.

(3) The final location of unbalances by field measurements with an unbalance detector which may be operated

[3] Journal A. I. E. E., Vol. 43, p. 1133, 1924.

by a lineman and which usually does not require interruption of telephone service, except momentarily.

Toll circuit office unbalances are briefly discussed and a special bridge for detecting and measuring the unbalances of composite sets is described. A mathematical treatment of the bridge method for locating unbalances and a discussion of the necessity of terminating the circuits involved in the tests in their characteristic line impedances are given in an appendix. The methods and apparatus described are widely used in the Bell System and afford operating telephone companies means for maintaining their circuits in the condition of minimum practicable unbalance.

The Theory of Probability and Some Applications to Engineering Problems,[4] by E. C. Molina. The purpose of this paper is to suggest a wider recognition by engineers of a body of principles which, in its mathematical form, is a powerful instrument for the solution of practical problems. Certain fundamental principles of the theory of probabilities are stated and applied to three problems from the field of telephone engineering.

Practices in Telephone Transmission Maintenance Work,[5] by W. H. Harden. This paper describes the practical application of transmission maintenance methods in a telephone system. The methods applicable to toll circuits of various types are first discussed, information being included in this connection on the maintenance of the amplifier circuits involved in telephone repeaters and carrier. Testing methods applicable to the local or exchange area plant are next described, the description including both manual and machine switching systems. The results accomplished in toll and local transmission maintenance work are considered from the standpoint of the kinds of trouble which can be eliminated and the effect which these troubles have on service.

[4] Journal A. I. E. E., Vol. 44, p. 122, 1925.

[5] Bell System Technical Journal, Vol. IV, p. 26, January, 1925; abstracted in the Journal A. I. E. E., Vol. 43, p. 1124, 1924.

The methods described in the main body of the paper relate particularly to tests of volume efficiency. Certain other transmission maintenance testing methods directly associated with volume efficiency tests are briefly described in an appendix.

Note on the Least Mechanical Equivalent of Light,[6] by Herbert E. Ives. In this paper the value for the brightness of the black body at the melting point of platinum recently obtained by the writer is used to find a value for the least mechanical equivalent of light using the latest values for the black body constants and the melting point of platinum. The spectral luminous efficiency curve obtained by Tyndall and Gibson is employed. It is found that over the entire range of probable values of the black body constants, the values for the least mechanical equivalent of light may be plotted as a straight line in terms of $\frac{C_2}{T}$ so that the present computations may be expressed in a simple equation in which any desired values of the black body constants may be inserted. Using the latest values the least mechanical equivalent of light is found to be .00161 watts per lumen. This is practically identical with the value obtained by using the author's earlier experimental determination using the monochromatic green mercury light, when combined with the Gibson and Tyndall luminous efficiency curve.

Photoelectric Properties of Thin Films of Alkali Metals,[7] by Herbert E. Ives. The thin films of alkali metals which deposit spontaneously on clean metal surfaces in highly exhausted inclosures are studied. The alkali metals, sodium, potassium, rubidium, and caesium, in the thin film form all exhibit, to a striking degree, the selective photoelectric effect first discovered in sodium-potassium alloy. Experiments on varying the thickness of the deposited film show that the selective effect occurs only at a certain stage of the film's development; for very thin

[6] Journal of the Optical Society of American & Rev. of Scientific Instruments, Vol. 10, No. 3, March, 1925, p. 289.
[7] Astrophysical Journal, Vol. LX, No. 4, November, 1924.

films the selective effect is absent, and it disappears again for thick layers of the pure alkali metal. The wave-length maxima of emission previously ascribed to the selective effect in the pure alkali metals on the basis of observations with rough or colloidal surfaces are absent in these thin films.

The Normal and Selective Photoelectric Effects in the Alkali Metals and Their Alloys,[8] by Herbert E. Ives and A. L. Johnsrud. The photoelectric currents from specular surfaces of molten sodium, potassium, rubidium, and caesium, and their alloys are studied at various angles of incidence for the two principal planes of polarization. The selective photoelectric effect is clearly exhibited only in the case of the liquid alloy of sodium and potassium. Wave-length distribution curves show maxima of emission, which are usually, but not always, most pronounced for light polarized with the electric vector parallel to the plane of incidence. The wave-length maxima previously assigned to the several elements are not confirmed; the maxima vary in position for the same element with the condition and mode of preparation of the surface.

Theory of the Schroteffekt,[9] by T. C. Fry. The current from a vacuum tube is composed of discrete particles of electricity which emerge according to no regular law but in an accidental, statistical fashion. The current therefore fluctuates with time. If the fluctuations are amplified sufficiently they may be heard in a telephone receiver as "noise"—a type of noise which is due to the mechanism of electron emission itself and not to outside interference. This noise is called the "Schroteffekt."

The effect is of certain importance from the telephone standpoint, for it appears that signals, the intensity of which is lower than that of the accidental current fluctuations, can never be rendered intelligible by vacuum tube amplification since the noise due to the statistical fluctuations of space current would be amplified to the same

[8] Astrophysical Journal, Vol. LX, No. 4, November, 1924.
[9] Journal of Franklin Institute, Vol. 199, p. 203, 1925.

extent and would mask the signals. Fortunately, however, the effect is much less pronounced under operating conditions than it is under the conditions which are most favorable for laboratory study. This is due to the fact that the presence of space charge under operating conditions smooths out the electron stream to a very material extent, and thus reduces the tube noise. The limitation imposed upon amplification is therefore not serious.

The present paper deals with what we have termed "laboratory conditions" as distinct from "operating conditions." Its principal result, arrived at by theoretical considerations, is: that if the electrons are emitted independently of one another the intensity of the noise in the measuring instrument is

$$S=\nu\,\overline{w}_1\,,$$

where ν is the number of electrons emitted per unit time and $\overline{w}_1$ is the average over all electrons of the energy that each would have caused to be dissipated in the measuring device if no other ever had been emitted.

When this formula is applied to the type of simply tuned circuit that was considered by earlier writers, it leads to substantially the same results as they had obtained. It is more general than these earlier results, however, and rests on less questionable methods of derivation. It is, in fact, more general than the problem of the Schroteffekt itself and applies equally well to the absorption of energy from any type of accidental disturbance which satisfies the condition that the individual electromotive impulses occur independently of one another. Static in radio telephony and certain types of crosstalk probably satisfy these conditions.

The Limitation of the Gain of Two-Way Telephone Repeaters by Impedance Irregularities,[10] by Geo. Crisson. After briefly mentioning the objects which certain inventors of repeaters have sought to attain, this paper describes in a simple way the phenomenon of reflection in a telephone line containing irregularities. It next shows

[10] Bell System Tech. Journ., Vol. 4, p. 15, 1925.

that the working gain of any two-way repeater, that is, a repeater whose gain in either direction does not depend upon the presence or absence of speech waves traveling in the opposite direction, is necessarily limited by the irregularities of the lines without regard to the structure of the repeater. Brief reference is made of the successful 21 and 22-type repeaters and to repeaters depending upon voice controlled relays which are not two-way repeaters in the sense that the term is used above. Finally, several repeater arrangements are described, which are typical of the schemes proposed at frequent intervals by inventors who seek to avoid the inherent limitations of gain imposed by impedance irregularities, and the fallacies in these arrangements are pointed out.

Voice-Frequency Carrier Telegraph System for Cables,[11] by B. P. Hamilton, H. Nyquist, M. B. Long and W. P. Phelps. Carrier telegraph systems using frequencies above the voice range have been in use for a number of years on open-wire lines. These systems are not suitable, however, for long toll cable operation because cable circuits greatly attenuate currents of high frequencies. The system described in this paper uses frequencies in the voice range and is specially adapted for operation on long four-wire cable circuits, ten or more telegraph circuits being obtainable from one four-wire circuit. The same carrier frequencies are used in both directions and are spaced 170 cycles apart. The carrier currents are supplied at each terminal station by means of a single multi-frequency generator.

The Transmission Unit,[12] by R. V. L. Hartley. The Bell System has recently adopted a new transmission unit, abbreviated TU, for expressing those quantities which heretofore have been expressed in miles of standard cable, or in Europe in terms of the βl unit. It is shown that units of this type measure the logarithm of a ratio,

[11] Journal A. I. E. E., Vol. 44, p. 213, 1925.

[12] Electrical Communication, July, 1924. London Electrician, Jan. 16 and 23, 1925.

and that the present art requires that this ratio be that of two amounts of power. Any of the proposed units may be so defined. Their essential difference is in the ratio chosen to correspond to one unit. The ratio chosen for the TU, $10^{0.1}$, makes it nearly the same in size as the 800-cycle mile, which has advantages. It also facilitates the use of common logarithms in preference to natural logarithms for which the ratio e of the βl unit is adapted. A distortionless reference system calibrated in TU is discussed, and conversion tables for the various units are given.

The Thermoinic Work Function of Oxide Coated Platinum,[14] by C. Davisson and L. H. Germer. Measurements of the thermionic work function of pure platinum coated with oxides of barium and strontium have been made simultaneously by two methods for the same segment of a uniformly heated filament. The theory of the measurements and the experimental arrangements are the same as used in an earlier experiment on the thermoinic work function of pure tungsten.[15] Filament temperatures accurate to $\pm 5°$, were found from the resistance of the filament at 0° C. in conjunction with the temperature coefficients of resistance.(1) In the Calorimetric method the equivalent voltage of the work function was computed from the sudden voltage change resulting from switching off the space current, due to the cooling effect of the emission. The determination was much more difficult than in the case of the tungsten filament, and measurements were made at the single temperature 1064° K. At this temperature the work function ϕ was found to be equal to $1.79 \pm .03$ volts.(2) In the temperature variation method it was found that, after the temperature had been changed suddenly from one value to another, the emission changed approximately exponentially from an initial value to a final steady value. The half value period of this change varied from a few seconds at high tempera-

[14] Physical Review, Vol. 24, p. 666, 1924.

[15] Davisson and Germer, Phys. Rev. 20, 300 (1922).

ture to over a quarter of an hour at low temperature. Interpreting this phenomenon as due to a progressive and reversible change of the character of the filament with temperature, the initial emissions after temperature changes from 1064° K. were used to determine the b constant of Richardson's equation corresponding to the equilibrium character of the filament at 1064° K., and similar measurements were made for the b constant corresponding to the character of the filament at 911° K. The two determinations lead, through the relationship $\phi=bk/e$, to 1.79 volts and 1.60 volts for the corresponding values of ϕ. For 1064° K., then, the two methods give values for ϕ in agreement. The measurements are, however, not sufficiently accurate to give any indication whether or not an electron within the metal possesses the thermal energy $3kT/2$. The various corrections made and possible errors are thoroughly discussed. It is pointed out that if the transition from the equilibrium state at one temperature to that at another had occurred so rapidly as to avoid observation, a disagreement of 25 per cent. between the values of ϕ given by the two methods would have been obtained which might have been misinterpreted.

Polarized Telegraph Relays,[16] by J. R. Fry and L. A. Gardiner. This paper discusses two forms of polarized telegraph relay which have been developed by the Bell System for metallic telegraph circuits and for carrier current telegraph circuits. Both relays are of the same general construction except that one is more sensitive and carries an auxiliary accelerating winding. The more sensitive relay is required to operate on reversals of line current of one milliampere, and at the same time retain its adjustment over long periods and faithfully and accurately repeat signals. It is interesting to note that under average conditions the ratio of power controlled by the contact circuit to that required by the line windings is about 5000 to 1. The parts entering into the magnetic circuit

[16] Journal A. I. E. E., Vol. 43, p. 223, 1925.

of this relay, except for a permanent magnet, are made of the new magnetic alloy (permalloy) recently developed in the Bell Telephone Laboratories. Permalloy lends itself to use in this relay because of its high permeability and very small residual effects. The design of the relay armature and the support for the moving contacts is such that contact chatter is practically eliminated. Photomicrograms showing practically no destructive action are given of the contacts of a relay which was in continuous service for 8½ months, during which time each contact made and broke its circuit approximately 45,000,000 times.

Note on Dr. Louis Cohen's Paper on Alternating Current Cable Telegraphy,[17] by L. A. MacColl. This is a criticism of two papers which were published in the Journal of the Franklin Institute by Dr. Louis Cohen. It is shown that Cohen's development of the theory of cable telegraphy contains many defects and errors, and in particular that his criticisms of H. W. Malcolm's book, "The Theory of the Submarine Telegraph and Telephone Cable," are without foundation.

Mutual Inductance in Wave Filters with an Introduction on Filter Design,[18] by K. S. Johnson and T. E. Shea. In this paper types of wave filters having interaction between certain of their elements—specifically, mutual inductance between pairs of coils—are analyzed and correlated to previously known types of filter circuits. Some of these filters exhibit unique and important characteristics. An introductory section treats of filter design in which the effects of energy dissipation and non-ideal terminal impedances, very important and difficult limitations on filter design, are treated.

As an aid in the correlation of various kinds of filters, equivalent electrical networks of the two-terminal and three-terminal varieties are considered and their application to important filter sections shown. It is pointed out that considerable economies in design, as well as

[17] Journal of the Franklin Institute, Vol. 199, p. 99, 1925.

[18] Bell System Technical Journal, Vol. 4, p. 52, 1925.

improvements in operating performance, often result from the employment of such equivalent networks.

Finally, there are indexed and depicted symbolically, the controlling characteristics—image impedance and propagation characteristics—of all economical types of "series-shunt" filter sections, including those types which employ mutual inductance between coils.

Notes on Recent Occurrences

AWARD OF LIEBMANN MEMORIAL PRIZE

THE Institute of Radio Engineers has announced the awarding of the Liebmann Memorial prize of $500 to Mr. John R. Carson of the American Telephone and Telegraph Company. The prize has been awarded in recognition of Mr. Carson's work on electric circuit theory, theory of selective circuits, and his invention of the single-side-band eliminated-carrier system of radio telephony.

THE RECENT SOLAR ECLIPSE

WHEN the eclipse of the sun swept down from Lake Superior toward New York City on January 24, 1925, and then out across the Atlantic, many engineers of the Bell System were at specially assigned posts within and near the path of totality to note any anomalous behavior of radio waves or of grounded telegraph lines. At the request of the American Astronomical Society, the American Telephone and Telegraph Company, through the Long Lines Department and through the Bell Telephone Laboratories, loaned facilities to assist in obtaining scientific information regarding the eclipse, the present eclipse having been unique in that it passed over territory exceptionally well provided with communication facilities. The use of long distance telephone and telegraph circuits enabled the observing astronomers to time more accurately both the eclipse and their photographing of certain details, such as the flash spectrum.

PROGRESS IN TELEPHOTOGRAPHY

ON April 4, 1925, the American Telephone and Telegraph Company inaugurated a limited service for the transmission of pictures over long distance circuits between New York, Chicago and San Francisco, following

three successful demonstrations during the preceding month of the method developed by Bell System engineers.

The first of these demonstrations was held March 1, when three test pictures were transmitted from Washington, D. C., simultaneously to New York, Chicago and San Francisco, and there distributed to the press. The second was on March 4, when nine news pictures of the Inauguration of President Coolidge were transmitted to New York, Chicago and San Francisco. The third was on March 19, when, without previous preparation, a dozen good news pictures of tornado damage in Illinois and Indiana, offered by various pictorial news services, were sent from Chicago to New York and San Francisco.

These demonstrations supplemented the initial demonstrations held in the summer of 1924, and their success promises early acceptance of the method as a useful and important contribution to modern commercial life.

In the July, 1924, issue of the BELL TELEPHONE QUARTERLY appeared a report of the first three public demonstrations of a system of transmitting pictures over telephone wires. The first of these was held on May 19, 1924, at which time several test pictures were sent from Cleveland, Ohio, to New York City. The second was held during the sessions of the Republican National Convention at Cleveland, June 8-13, 1924, when actual pictures of the convention were transmitted from Cleveland to New York for distribution to the press. The third was held from June 22 to July 3, at which time pictures of the Democratic National Convention, then in session in New York City, as well as several pictures showing cartoons, handwriting and finger prints, were transmitted to Chicago for distribution there. The recent demonstrations, therefore, extend the range of telephotography to transcontinental distances, the line over which the pictures of the Inauguration were sent being 3,600 miles in length.

The first picture of the Inauguration of President Coolidge, that of the floral tribute to Mrs. Coolidge pre-

sented by ladies of California, was started on the circuit from Washington at 10.22 a.m., Eastern standard time. Extra editions of newspapers carrying this picture were on sale in San Francisco before 11 a.m., Pacific standard time, and in Chicago at about the same time. In all, nine official pictures, including one of the administration of the oath taken from a distance of about 125 feet, were transmitted up to 5.45 p.m. From 25 to 40 prints of each picture were made at New York and Chicago and about 100 of each at San Francisco and furnished to newspapers and others for reproduction. Practically all the principal daily papers in the three receiving cities used the pictures, in some cases several being used on a display page. In some instances, enlargements to four and five newspaper columns in width were made and printed with good results.

The demonstration of the method on March 19 in connection with tornado damage in Illinois and Indiana was perhaps even more impressive. In this case no previous arrangement to secure or send pictures had been made. The normal organization was used and for the first time pictures were accepted for transmission from various pictorial news services, as offered. Pictures were transmitted beginning 6.32 p.m., Central time, until 12.48 a.m., and a dozen were distributed to the press in New York and San Francisco. All the principal dailies and pictorial press associations used the tornado pictures with uniformly good results.

Noticeable improvement in the quality of the photographs transmitted is noted as a result of several months of continued experimentation and refinement since the initial demonstrations in 1924. Comments of many representatives of the press were to the effect that the pictures now being transmitted are commercially satisfactory and that the system now being offered for commercial use in New York, Chicago and San Francisco is a practical solution of the problem of rapid and dependable telephotography.

The new method is a refinement of the line structure method used in 1924, by which the lines are practically eliminated in the received picture. Transmission of a 5″ x 7″ picture takes about seven minutes and the picture is received in such form that, after photographic development of the usual sort, it is practically indistinguishable from an ordinary photograph and is ready for newspaper or other reproduction. Line drawings, handwriting, and printing can also be transmitted. As films can be used for transmission while still wet, this system eliminates the delay which would otherwise be caused by drying and by making special sending plates.

The method is made available to the public for the present for sending and receiving photographs only at New York, Chicago and San Francisco, and it is announced that the extent to which it is installed on the various long distance lines will depend entirely upon the demand which arises for this type of service. As has been demonstrated in previous tests, the system is also applicable to radio transmission of pictures when atmospheric conditions are such that steadiness of transmission and freedom from interference can be assured.

J. EPPS BROWN

J. EPPS BROWN, Chairman of the Board of Directors of the Southern Bell Telephone Company, died at Atlanta, Ga., on March 27.

Born in 1867 at Newberry, S. C., Mr. Brown received his early education at Mount Bethel Academy and Erskine College at Due West, S. C. Upon his graduation he entered the insurance field, first in South Carolina and then in Georgia, where he made his headquarters at Americus. In May, 1899, he entered the service of the Bell System as manager of the small exchange of the Southern Bell Company at Americus. His career from then on was one of continuous advancement.

He soon attracted the attention of Col. W. T. Gentry,

then General Manager and later President of the Southern Bell Telephone and Telegraph Company, and he was brought to Atlanta as chief clerk in Colonel Gentry's office. In 1901, he was appointed special agent to the general manager, and in 1904, served as acting general manager. He was appointed general manager in 1907 and in 1909, was elected vice-president and general manager.

In 1914, when the Southern Bell and Cumberland Companies were placed under joint management as the Southern Group of the Bell Telephone companies, Mr. Brown was promoted to first vice-president, and five years later, in 1919, he was elected president of the entire system, having risen from the ranks to the highest position in the organization.

On June 10, 1924, Mr. Brown resigned as president, and was elected Chairman of the Board, which position he held at the time of his death. He was also a leader in civic affairs, a member and former director of the Atlanta Chamber of Commerce and a director of the Atlanta National Bank.

THE ANNUAL MEETING

AT the Annual Meeting of the stockholders of the American Telephone and Telegraph Company which was held in the headquarters building at 195 Broadway, New York, on March 31, the directors were reelected. The increase of the authorized capital stock by $500,000,000 was voted, and the transactions of the past year were approved.

There were 5,835,040 shares voted by proxy or in person, which represented 65.45 per cent. of the outstanding stock.

GENERAL STATISTICAL CONFERENCE

A GENERAL Statistical Conference was held in New York from April 1 to 8, inclusive, and was attended by those members of the Accounting Depart-

ments of the Associated Companies who are engaged in the development of statistical work, and by members of the Chief Statistician's Division of the American Telephone and Telegraph Company. This was the first conference in the Bell System to be devoted entirely to statistical matters and it provided the first opportunity for the Statisticians of the Associated Companies to come together for the discussion of their common problems and for the consideration of plans for the expansion of statistical work along profitable lines.

The need for more extensive and more coordinated statistical work throughout the Bell System is largely a result of the rapid growth of the business in magnitude and complexity. The general theme which ran through the discussion related to the ways in which the Statisticians can contribute to the management most effectively, and at the same time most economically, through the development of adequate processes of analysis and presentation of the significant facts pertaining to the various phases of the business.

The conference was opened by Mr. S. L. Andrew, Chief Statistician of the American Telephone and Telegraph Company, who summarized the status of statistical work in the Associated Companies at the present time and outlined the objectives of the conference. The first subjects discussed in detail covered the mechanics of statistical work. Extended consideration was then given to the question of appropriate graphic methods of analysis and control, not only as related to over-all company performance, but also as related to departmental results and area activities. Personnel statistics were discussed at some length, with particular emphasis upon the contributions which the Statisticians may make in the further analysis of sickness experience and wage data.

Methods of collection, analysis and presentation of general economic statistics were discussed, with special reference to the study of current business conditions and future business prospects in Associated Company terri-

tories; and methods of relating general business statistics to telephone statistics were considered. The application of mathematical methods of analysis to telephone statistics was another subject taken up; this subject included the use of such methods both in the analysis of current company performance and in estimating probable further performance for Provisional Estimate and other purposes. The discussions also embraced several matters pertaining to the organization of statistical work.

The free interchange of views which characterized the proceedings of the conference was especially helpful in acquainting the members with the results achieved, up to the present time, in the various phases of statistical work throughout the Bell System and in indicating the scope and character of the work which might profitably be undertaken in the future.

Organization Changes

American Telephone and Telegraph Company

Harry B. Thayer elected Chairman.

Entered employ of the Western Electric Company as clerk, 1881; Manager, 1883-1902; Vice-President, 1902; Vice-President and General Manager, 1908; President, Western Electric Company, 1908-1919; Vice-President, American Telephone and Telegraph Company, 1909-1915 and 1918-1919; President, American Telephone and Telegraph Company, June, 1919.

Walter S. Gifford elected President.

Entered the employ of the Western Electric Company at Chicago in 1904, later becoming Assistant Secretary and Assistant Treasurer in the New York office of that company; Chief Statistician, American Telephone and Telegraph Company, 1908-1915; on leave of absence to serve as Director of United States Council of National Defense, 1916-1918; Comptroller, American Telephone and Telegraph Company, 1918; Vice-President in charge of finance, 1919; Executive Vice-President, 1923.

David F. Houston elected Financial Vice-President.

United States Secretary of Agriculture, 1913-1920; United States Secretary of the Treasury, 1920-1921; President, Bell Telephone Securities Company, 1921.

Pacific Telephone and Telegraph Company

G. E. McFarland elected Chairman of the Executive Committee.

Entered the employ of the Bell System as Manager and Lineman, Marshalltown Telephone Company, 1880; Superintendent of Construction, Iowa and Minnesota Telephone Company, 1882; General Superintendent,

1884; Iowa Union Telephone and Telegraph Company, Superintendent, 1886; General Superintendent, Iowa Telephone Company, 1906; First Vice-President and General Manager, 1907; General Manager, Northwestern Telephone Company, 1909; President, Pacific Telephone and Telegraph Company, 1913.

George J. Petty elected Vice-President.

Entered the employ of the Pacific Telephone and Telegraph Company, 1889; Assistant Secretary and Assistant Treasurer, 1907; Treasurer and Assistant Secretary, 1919; Treasurer and Vice-President, 1922; Treasurer, 1924; Vice-President, 1925.

BELL TELEPHONE COMPANY OF CANADA

L. B. McFarlane elected Chairman of the Board of Directors.

Entered employ of The Bell Telephone Company of Canada, 1879, as Manager of Eastern Division; General Manager, 1906; Managing Director, 1911; President, 1915.

C. F. Sise elected President.

Engineering Department, American Telephone and Telegraph Company, 1897; Superintendent of Toll Lines, Bell Telephone Company of Canada, 1899; Assistant General Superintendent, 1903; General Superintendent, 1906; General Manager, 1913; Vice-President and General Manager, 1918.

J. E. Macpherson appointed Vice-President.

Entered employ of The Bell Telephone Company of Canada as Traveling Auditor, 1892; Local Manager, Ottawa, 1897; District Superintendent, 1910; Executive Assistant, 1923.

Paul A. McFarlane appointed General Manager.

Entered employ of The Bell Telephone Company of Canada, Plant Department, 1904; District Superintendent, Toronto, 1911; Commercial Engineer, 1916; General Commercial Manager, 1920.